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DWIGHT H. GREEN, Governor

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DEPARTMENT OF REGISTRATION AND EDUCATION
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ADDRESS OF THE PRESIDENT

SOME PERSONAL RESPONSIBILITIES OF SCIENTISTS

OTIS B. YOUNG
President, Illinois State Academy of Science, 1944-45

Our attentions are so often drawn to the momentous emotion-stirring events both at home and abroad, that we relegate to the background those questions which do not clamor for immediate attention and action. Yet a delay in considering a question and the failure to prepare for a situation may result in a catastrophe or in postponement of a major discovery.

One such question to which science should seriously dedicate itself, I believe, is the position of science itself. Science has a place of unprecedented importance, it affects the lives of most people, it carries the major part of the gigantic burden of adding to the total of human knowledge; yet in its rapid expansion into our educational, social, economic, and industrial life, it is losing much of its recently acquired identity. Effective and desirable unity among scientists is difficult to obtain. Many different groups, professions, organizations, research institutions, and foundations are conducting scientific work under many different names, and frequently they are not linked with other workers in the basic sciences to which their own work is so closely related. Yet all are engaged in the discovery of the secrets of nature and their classification and utilization. This motive should be a far stronger bond than that which serves to hold together many another group.

It is the highly trained scientific personnel who developed and largely perfected the scientific method of thinking, the application of which has advanced civilization. Such people have achieved the developments that distinguish the world of today from that of the stone age. Their devices determine today's methods of warfare in which the victor is the one who uses superior equipment. Manpower odds must be tremendous to make an exception to this statement. A great industry may be founded on one successful research project. Is it necessary to elaborate on the importance of such discoveries as radar, the sulpha drugs, plastics, electrical and mechanical power, the X-ray, and the airplane? The list might be extended indefinitely, yet the exploration of physical and biological realms has scarcely begun.

Although realizing the tremendous influence of science, we should remember that its motives remain restricted, its activities limited, and its component groups scattered. The science which has given the world such vast knowledge for both human betterment and destruction, has generally remained neutral on moral questions. Its products may be used for either good or evil, but it has

exerted no concerted influence to control their uses. The primary motive is only to discover, classify, and apply the laws of nature; nevertheless the individual scientist is still a human being, and not all his vital needs are served by his diligent labor under this primary motive.

Some of the limitations may be indicated by the following queries:

(1) In case some highly meritorious legislation is desired, do you constitute a well recognized political, lobbying, or pressure group? Would you be willing to become one upon the recommendation of the proper authorities?

(2) The history of science reveals many workers who tried to carry on, in spite of poverty, inadequate facilities, and social abuse. What corrective methods have originated within professional groups concerned?

(3) One person in seven normally dies of cancer. Should research on this vital problem be largely curtailed until voluntary public subscriptions finance it? Should research be more effectively subsidized?

(4) Does your salary average more than one-half the income of a professional practitioner with equivalent training?

(5) Are you cooperating systematically and continuously in carefully planned activities with State and Federal Departments?

(6) Are you willing to make recommendations restricting the use of your products when public welfare is jeopardized?

(7) If you are an educator, what percentage of students take basic science courses in comparison with other subjects?

(8) What is the relative cost per student in your department compared with other more personal subjects? Are all schools financially able to equip a high ranking science department? Do instructors of science work under conditions as suitable as those in other subjects?

(9) Do you give assistance and protection to needy scientists suffering under unquestionable injustices and persecutions?

(10) Are you carefully watching sources of research material, such as archeological, which may become lost, damaged, or destroyed?

(11) Do you agree that the responsibility for a large project can be borne better by an organization than by some interested individual? If so, what rules and regulations has your organization established?

(12) What means of close cooperation have been provided among the various State Academies of Science? Likewise with the National Academies beyond usual mere affiliation as with the A.A.A.S.?

(13) By what means of systematic publicity is the general public informed about the values of research? Does the public mind give the credit for it to the proper sources? Will that public support your activities expended in its behalf?

(14) Advanced educational training has been largely curtailed during the war; what action is planned to compensate for the resultant deficit of highly trained scientists?

(15) In nearly any of the medium sized and small institutions of this State, there are several capable and ambitious members of the Illinois Academy of Science who are far too limited by both time and facilities to conduct independent research. Have large high quality projects been subdivided so that members in different localities may take part and thus advance professionally?

(16) If you are allowed to live in the so-called "ivory tower", largely immured from disturbing influences

and able to pursue your research and other professional activities to the full extent of your energy and capability, will you concentrate temporarily on supplying the necessities of life to alleviate the suffering which accompanies economic depressions, low salaries, and unemployment?

(17) After witnessing the changes in nations abroad which have been wrought by those extreme force-systems of government, as in Germany which to a large extent made possible the present global war, can you believe that organizations with excellently e d u c a t e d personnel should fail to be ready to protect at all times with all means at their disposal our democratic form of government?

(18) S h o u l d not intellectual groups, using a reasonable and practical interpretation consider the "four freedoms" not only an ideal, but a workable and permanent goal? Should not scientists continue in time of peace to defend America against subversive infiltrations as "The fifth columns" which may again attempt, as a social cancer, to eat at the vitals of duly established and regulated law and order?

(19) From a business viewpoint, is a low financial balance difficult to explain if you not only give away the valuable results of your research, but also pay publication costs to hasten the process of giving them away?

(20) An underlying thought of many observers of prominent conferences for the settlement of differences is, "Has humanity, through suffering and education, learned yet to cooperate for mutual benefit?" Was torture an indispensable factor in causing you to perform excellent research, or did you respond to your own will and interest?

Some may consider the foregoing questions unnecessarily critical or that they do not come within the usual reaches of science; if so, their attention should be called to a changing and dangerous trend that is founded on a debatable assumption, a trend to which many professions and organizations are receptive and one that will grow as the stress of war diminishes. This trend is the tendency to relegate the sciences to a position of lesser importance, and instead, for the purpose of maintaining human harmony, to rely in the post-war period on social sciences—philosophy, religion, history, economics, and education. Although there is much merit in asserting the dependence of peace upon better human relations, the assertion does not solve the problem. These social fields, significant and indispensable as they are, have not yet proved effective in maintaining international goodwill.

If the real scientists neglect to expand their activities and influences, with subsequent loss in prestige and curtailment of research, it will be a step toward unpreparedness—toward popular indiffenence and complacency—toward the next war. Science, so valuable in war, is equally effective in peace. No well-balanced solution of international ills, armed conflict and chaos, will discourage or handicap science. We must depend on science, even when no crisis exists.

Mankind has often turned to philosophy for answers to urgent questions, and perhaps always will, for we have no assurance that all the secrets of nature will ever be discovered. Yet such a practice recognizes the inadequacy of science and man's limitations in accepting responsibility for his own welfare. Our wars are extreme examples of our failures.

Time and again society has tried out its variations of behavior patterns, each with merits, each with faults. And all too often the merits are submerged and forgotten. We cannot help but wonder whether such speculation and trial-and-error methods are always necessary, and whether it may not be possible to solve more and more problems by the fact-finders, by scientific unbiased investigators. Does the price paid in terms of human life and suffering warrant delay in the permanent universal adoption of established knowledge? Such questions are with us always, in times of both peace and war.

This discussion is not an attempt to include all the issues of the universe nor to encourage an unreasonable expansion in science's objectives, but it is an emphatic appeal for the application of scientific methods to additional significant and vital realms. We hear the agonized voices of the impoverished, the suffering, and the dying; we see the crosses which mark the resting places of the war dead. We comprehend the price which, down through the ages, humanity has paid in the hope of attaining higher ideals and better ways of life. We look candidly at the results and see little cause for optimism. When we consider the future, our faith in the traditionally appropriate administrative non-scientific groups is at best only moderate. We wonder what a different approach might contribute, and if it would be welcomed and supported.

It may be that, great though its attainments, science will truly come into its own when it produces workable solutions to the old questions and problems that are the fundamental causes of human unhappiness and of national and international strife.

In conclusion, our rapidly maturing science should expand tremendously, should assume responsibilities adapted to the demands of its members, should protect itself through representation rather than restrict its activities and trust others to show benevolence, should continue its eminent part through research and the application of research in making the lives of people more full and complete, should influence the uses of discoveries for human betterment rather than for destruction, and should undertake the task of assisting with the solution of momentous borderline issues. Much may be accomplished through effective organization and through sustained active participation of all who labor in one of the noblest of all professions, the great brotherhood of science.

AGRICULTURE

EFFECT OF VACUUM PASTEURIZATION ON THE QUALITY OF CREAM PRODUCED IN SOUTHERN ILLINOIS

HAROLD C. BRACKETT
Producers' Creamery, Carbondale, Illinois

One of the basic solutions to the land use problem of southern Illinois is grassland farming which implies extensive pasturage with livestock, particularly dairy cattle, beef cattle, and sheep. Dairying is beset with a particularly serious problem because of the widespread presence of wild garlic in pastures in southern Illinois. Milk produced from pastures infested with garlic absorbs objectionable odors which persist through all the regular processing into commercial products.

In addition to wild garlic, pepper grass also causes objectionable odors in milk and cream products. Poor care of cream before it reaches the processing plants also contributes to the high percent of low scoring butter produced in southern Illinois. "Poor care" might include carelessness on the farm, delays and lack of refrigeration in transit to market, and ineffective processing techniques or any combination of these factors. The remedy for this kind of defect in butter as an end-product of milk and cream is a methodical program of quality improvement beginning with the milk as it comes from the cow and ending with the cream as it enters the churn. In other words, improvement in this category involves management practices under the control of the human element.

This paper deals largely with the defect caused by the carry-over of absorbed weed and feed flavors into manufactured butter and how this defect may be corrected once these odors are absorbed.

It is a well known scientific fact that flavors of weeds and feeds eaten by cows a few hours prior to milking are absorbed on the surface of the fat globules and thus are carried into the milk. One practical suggestion is to take cows off pastures infested with objectionable weeds four or five hours before they are milked. Since this is a management factor difficult to control, sometimes making an extra chore and possibly discouraging the very enterprise itself, much "garlicky" cream will undoubtedly find its way to the creameries. The principal problem in handling such cream is to remove these flavors from the butter fat, thus rendering the products more salable without impairing the physical or chemical properties.

Early experimental work to rid cream of weed flavors was along

chemical and physical treatments. The chemical methods, particularly with chlorine compounds, were never highly acceptable because of certain violations of the Pure Food and Drug Act. A few cases of litigation and adverse publicity followed the early trials with these chemical methods. The ultimate product appeared to be no improvement over the original. Most chemical methods involve the use of very exacting amounts of reagents, with the ever present hazard of using either too little or too much. Because of this hazard, disastrous financial losses have been encountered among dairy manufacturers.

Mechanical methods designed to release absorbed flavors involve both applied pressure and vacuum treatment. Although some pressure systems are known to have had a marked effect in improving the quality in cream, none are apparently capable of completely freeing the fat globules of absorbed odors and flavors.

The first vacuum type units used in the United States were essentially improvised vacuum pans or tanks, some equipped with nozzles for spraying the cream into a vacuum chamber. Others were equipped with steam jets to agitate or "steam wash" the cream while under reduced pressure. Most of these units employed a high pasteurizing temperature, some as high as 240°F, just previous to the reduced pressure treatment. These early attempts resulted in a definite improvement in flavor but in many cases the physical structure was usually impaired —specifically a breakdown in the "body" of the butter occurred and was difficult to overcome.

Simultaneous to this early work in this country, Mr. F. S. Board, an internationally eminent authority in dairy technology, and his associates were carrying on experimental work along the same line in Australia and New Zealand. One product of their research was a triple-stage vacuum pasteurizer and deodorizer which was called "Vacreator". Small experimental units were installed by the Dairy Departments of Iowa State College and Oregon State College in 1940. It appeared that this equipment when properly handled could eliminate the objectionable flavor without impairing the physical quality of butter. The work at these two institutions gave the dairy industry of this country their first opportunity to observe new equipment which promised to revolutionize cream processing techniques.

By a cooperative arrangement with Iowa State College, this organization early in 1941 was permitted to scrutinize and evaluate the new equipment and its operation. The results were immediate and highly satisfactory. Negotiations with Mr. Board were made and the third machine to be installed in a commercial plant in this country was purchased by the farmer-cooperative with which the author is affiliated.

Since 1942 this organization has built its qaulity program around the new "Vacreator". Striking results have been obtained in producing higher quality butter; for example, all cream received at the plant in April 1943 testing 0.40 percent acidity or lower made 92 score butter. Most of the cream was unquestionably "garlicky" when it was received. In 1944 less than four percent of all the butter churned was below 90 score, as compared with 47 percent below 90 score in 1939. The quality of butter and the percent of 92 score butter produced in 1945 indicates an improvement over that of 1944. It is hoped that butter scoring less than 90, commonly referred to as "under grade", may be reduced to two percent for 1945

This small percentage represents deterioration in quality and the production of objectionable flavors due to decomposition and cannot be remedied by the vacuum—high-temperature method. Only by an aggressive educational program directed at the source of trouble, the farm itself with its management factors, can this defect be eliminated.

CONCLUSIONS

This farmer-cooperative organization has gone beyond the purely commercial motives in trying to produce high quality butter from low quality cream. It is clearly demonstrated that the problem of low scoring butter for which southern Illinois has long been notorious can be handled successfully. Essentially all the objectionable feed and weed flavors common to the cream of this area have been removed mechanically by the new "Vacreator" process.

The final stage in the improvement program to put southern Illinois in the 92-93 score butter class involves education of the producers in handling milk and cream on the farm. Hazards can be eliminated all along the way from the time the milk is taken from the cow until the cream is on its way to the market. Reducing the time in transit to the processing plant will be a post-war problem easily solved.

The dairymen of southern Illinois should be encouraged to know that an old "mill stone" is being removed and that in time this area may become much more important as a dairy-producing region because of improved methods of processing as described herein.

FLUCTUATIONS IN SAN JOSE SCALE INFESTATION

STEWART C. CHANDLER
Field Entomologist, Illinois Natural History Survey

San Jose scale is an ever present menace to fruit trees of Illinois, apple and peach especially which may require annual spraying in order to hold it in check. It is especially severe in the southern third of the state, doing its greatest damage south of a line between St. Louis, Mo., and Vincennes, Ind.

Because of the fact that some growers would like to omit the dormant spray for scale in seasons when the infestation is light and take special pains when it is severe, the Illinois Natural History Survey has conducted an annual survey of conditions in apple and peach orchards in southern Illinois and reported the results at fruit meetings and through the press. From 150 to 200 orchards are examined, about equally divided among apple and peach, in the principle fruit-growing counties of southern Illinois. Usually about 15 or 16 counties are included in the survey, extending from Marion and Richland counties in the north to Pulaski and Massac in the south. Frequent inspections are made in other regions north of this territory, but since infestation is much less severe there, they are not included in this discussion. As nearly as possible the same territory is covered and very frequently the same orchards are inspected each year, so as to increase the probability of accuracy of the information secured on yearly trends.

After inspecting each orchard the infestation was set down as "Moderate to Severe" or "None to Light". This appears to be the most practical method of recording the extent and prevalence of the insect. Because of the nature of the insect and the enormous number of individuals, there is no easy way of recording by percentages. "Moderate to Severe" was made to refer to the infestation in one or more parts of the orchard but not all over the orchard, since the oil sprays now available for the grower make a heavy infestation over an entire block of trees unlikely. Also most growers have found from sad experience that a single spot of heavily infested orchard may mean a great loss to the entire block of trees by the end of another season, if not thoroughly sprayed with a sufficient strength of oil in the dormant season that follows the discovery of the infestation. Figure 1 shows the effects of scale on a single peach tree.

Figure 2 shows the percentages of peach and apple orchards over a 15-year period in which a moderate to severe infestation of San Jose scale was found in some part of the orchard. It may be seen that in these fifteen years (1930-1944) there were high peaks of infestation about every third year. In those years from 40 percent to 50 percent of the apple orchards and from 58 percent to 72 percent of the peach orchards had "Moderate to Severe" infestations. These years were 1931, 1934, 1937, 1941, and 1944. The only exception to the three-year rule was in 1940, and this was true only because the infestation in 1941 was still

FIG. 1.—Results of heavy infestation of San Jose scale. Some of the infested branches began to grow in the spring but they finally died.

higher than the high percentage in 1940.

It will be observed that the infestations in peach orchards are almost invariably higher than in apple orchards. This was found to be true, not only in orchards side by side, but even in those interplanted, peach and apple together. This may be due in part to the factor of plant susceptibility. We know that certain trees or even varieties of fruit are much more susceptible to the attacks of certain insects and diseases than others. It may also be due in part, and possibly quite largely, to the fact that growers apply sprays for various insects and diseases to apple more than to peach, and that helps to hold the scale in check. Summer oils used for coddling moth control are probably a factor in checking the scale during the season. These are never applied to peach.

In attempting to explain the tremendous variations from year to year, especially the big decreases following the peak years, some of the various factors which affect infestation of San Jose scale are here considered:

1. Winter mortality.—Every winter appreciable numbers of scale insects are killed by low temperatures. Counts of survival over these years, although not made regularly, have been found to range from 2 percent live to 75 percent live in the spring, after the cold of winter has passed.

2. Length of breeding season.—San Jose scale, unlike some insects, continues to reproduce as long as the weather is reasonably warm. In some long, mild autumns, I have found crawling nymphs in the middle of December following mild weather in November. At other times there is little reproduction after the middle of November, even in the extreme southern areas of the state.

3. Parasites and predators.—This is a very important factor. Some years very high percentages of scale have been found destroyed by their insect enemies. Sufficient study has not been given to the enemies of this

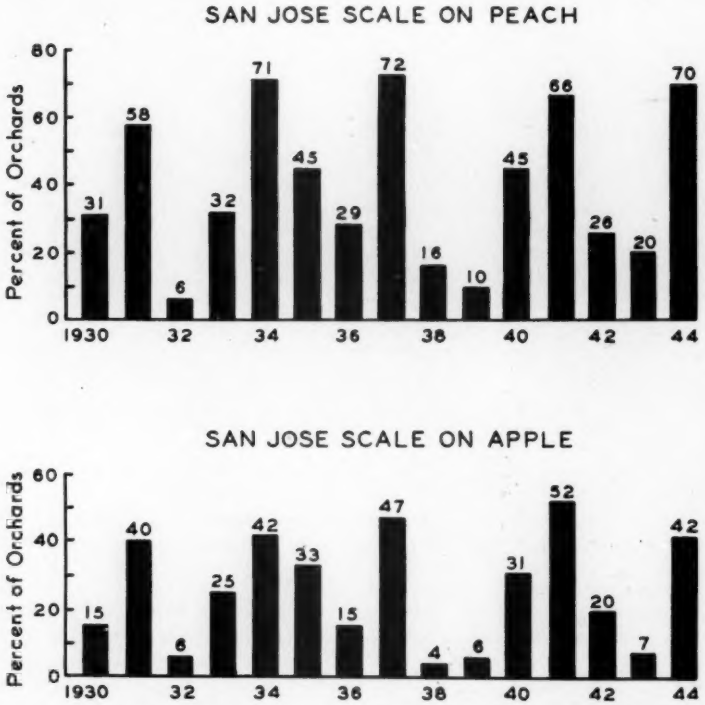

FIG. 2.—Percentage of orchards showing moderate to severe infestation of San Jose scale during the years 1930-1944.

particular insect, but in general it has frequently been found that the increase in the host insect will bring about so great an increase of its enemies that it is reduced to a point that results in lack of food for the parasites. In other words, these parasites and predators do such a good job that they destroy their means of livelihood and they themselves die off. It is entirely possible that this happens to a considerable extent with the San Jose scale.

4. Control by the grower.—During the winter following every year in which scale becomes serious, growers make particular effort to do a thorough job of spraying. Whereas some years they might omit the dormant spray, at least in some blocks, this particular season every tree is sprayed and often a stronger than usual dosage of material is used. Growers may not realize, without being told, the seriousness of the situation, since San Jose scale is a very tiny insect lying flat against the bark, and many people cannot see it until thousands of individuals are massed on a branch. Every effort is made to publicize the scale situation in these peak years. It is entirely possible that the special efforts made by growers to reduce the population is another important factor in these fluctuations.

SOME WAR-TIME DEVELOPMENTS IN SPRAYING ILLINOIS FRUITS

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Many of the advances during the past few years in spraying fruits are not the direct result of war-time conditions, but have been accentuated to a considerable extent because of these conditions. The purpose of this paper is to present some of the recent changes in practical spray schedules and the factors which have brought them about.

For several years prior to the war, nicotine sulphate was used in a limited way to supplement the program of coddling moth control in apples. Its advantage is that it can be used until immediately before harvest without the necessity of washing the fruit in order to comply with spray residue regulations. Experimental work has shown also that nicotine products are less injurious to the foliage of apple trees than arsenate of lead. Fruit properly sprayed with nicotine usually has less stings because the coddling moth larvae are killed before they actually have an opportunity to eat into the fruit skin. Although this program was well under way before the war, it was encouraged to a much greater extent because it appeared that the domestic supply of arsenicals would be limited. Nicotine products showed much greater promise of being available in sufficient quantities and consequently were included in many spray programs. Even though the situation is reversed at present, that is, nicotine preparations are scarce whereas arsenicals are available in fairly satisfactory quantities, many growers prefer to use nicotine sprays because of the advantage in growing high quality fruit without the need of washing. This trend will continue long after the close of the present war.

Hormone sprays made of a sodium salt of naphthalene acetic acid were also being used experimentally at the outbreak of the war. Their principal purpose is to keep the apples from dropping from the trees as they approach maturity. With a shortage of labor on fruit farms, however, it soon became evident that the same material could be used to prolong the harvest period and consequently level out necessary peaks of labor. The material is especially effective on long stemmed varieties of apples such as Delicious and Jonathan. It is least effective on short stemmed varieties such as Winesaps.

DDT, which is the common designation for dichloro diphenyl trichloroethane, is a new material which has had a great amount of experimental work for war-time uses. It has not been developed primarily as a spray material, but rather because of its promise in controlling insect pests of the Armed Forces. A certain amount of experimental work, however, has been done with this material in order to discover its adaptability for controlling insects injurious to fruit. It has not yet reached the stage where definite recommendations are offered. In

fact, for the first time this year limited amounts are being made available for experimental work to be carried on by a few commercial orchardists. It seems to have very definite promise of fortifying the nicotine spray program in order to further combat the coddling moth. It is well known that this material is very effective in controlling many insects. Just what its effects will be, however, in damaging beneficial parasites is yet to be determined. In fact, so little definite information is known about what can be accomplished with DDT that its future lies in the field of speculation. Its potentialities, once realized, will probably decrease the number of applications needed during a growing season and thereby appreciably reduce the cost and the labor needed to grow good fruit.

Another very new material is an emulsified wax made of a mixture of vegetable oils and mineral waxes. The primary purpose of this is for spraying heavily blossoming trees at the time of full bloom in order to cover some of the blossoms thereby giving the remaining ones a better chance of setting fruit than when all are equally competing for the stored-up energy in the tree. The success of this depends upon the physical aspect of sealing the pistils thereby eliminating the possibility of the entrance of pollen. In addition to the value of helping trees to set fruit, it has the added possibility of regulating the set. If this condition is later to be corroborated, a great deal of labor normally used in thinning overloaded trees could be saved. Not enough experimental work has been done with wax emulsion sprays to offer definite recommendations for spray schedules. A small amount of material is being made available to commercial growers for experimental work for the first time this year. It will probably take several years before the full value of wax emulsion sprays is known.

In addition to the various new materials which have been mentioned, other developments have been speeded up because of war-time conditions. Although dusting of peaches and apples has been done for a number of years, the labor-saving angle of this practice has been especially appreciated since the outbreak of war. Many more dusters are now in use because an orchard can be dusted in much less time than it takes to apply a wet spray. Even hormone dusting is now accepted as an efficient and effective method of applying hormones to prevent the well known summer drop in apples.

Innovations in spraying equipment may also be attributed to labor shortage due to the war. Larger and more powerful sprayers are coming into common use, the so-called speed sprayer being one of the latest developments. The principal advantage of the new speed sprayer is that the tractor and spray outfit can be operated by one man. Airplane dusting, while not entirely new from the standpoint of field crops, is being discussed by Illinois fruit growers and has been tried in a small way by a few commercial orchardists in other parts of the United States.

The recent trend in spray programs in Illinois is characterized by improved and new spray materials, more powerful machinery, and a relatively smaller need for labor. This has been caused largely by the present war and its many effects on the practical fruit growers.

BORAX CORRECTS TIPBURN IN GREENHOUSE LETTUCE

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Boron deficiency has been unquestionably demonstrated in many soils of the United States and Europe. Certain soils along the eastern sandy coastal plains of the U. S. require borax for successful vegetable growing. The old soils of Virginia, Tennessee, and Kentucky will not now grow alfalfa successfully without borax application. Seed production, higher hay yields, and greater length of life of stands have resulted from borax applied to alfalfa. Boron deficiency is common in Michigan, especially for alfalfa, sugar beets, and some vegetable crops. In the extreme Northwest, some soils have been found deficient in boron.

In Illinois, boron deficiency has been shown to exist in several soil types throughout the state. Alfalfa is especially sensitive, the older soils of southern Illinois having shown the greatest response to borax. It is reported that a direct relationship exists between the age or intensity of weathering of a soil and its available boron content. Such a situation exists with potassium availability, suggesting that the same weathering agents place both potassium and boron among the dearer soil nutrients. However, there is no known relationship between the two elements and there is generally much more total potassium than boron in soils.

The rates of application of borax to correct boron deficiency suggest that only very small amounts of boron are required for normal plant development when compared with nitrogen, phosphorus, and potassium.

The requirements for boron among the different species of crop plants appear to vary considerably. Soils may be deficient for some crops and sufficient for others. Apparently the cereal grains and forage grasses have a low requirement, whereas legumes, tomatoes, root crops, cole crops, tobacco, sunflowers, and other plants have a high requirement.

The problem presented herein came to the attention of the Agricultural Extension office in 1944. Two Williamson County greenhouse operators reported peculiar symptoms in leaf lettuce appearing just at marketing time. Dr. R. H. Bray, University of Illinois, Department of Agronomy, suggested that the trouble might be boron deficiency.

DESCRIPTION OF SYMPTOMS

McHargue and Calfee (1) have shown that boron deficient head lettuce plants show necrotic tissue near the leaf margins and over the growing point. Moinat (2) grew head lettuce in nutrient solutions with and without boron. Plants without boron had thick, small, cupped, brittle leaves; furthermore, brown spots and waxy exudations appeared on the younger leaves, followed by the browning and death of the growing point. The leaf lettuce observed in the Herrin commercial greenhouses in 1944 exhibited some of the symptoms described above. Mr. Edward

Ridgeway reported that his lettuce was stunted and just at marketing time tipburn damage spread rapidly over the entire planting, causing serious financial loss. In addition, Mr. Ridgeway observed that the plants "bled" profusely with the whitish exudation. Furthermore the leaves seemed brittle and in handling they gave a metallic, rustling, paper-like noise.

Since leaf lettuce is harvested in a very immature stage as far as the life history of the plant is concerned, the growing point was not examined for evidence of nutritional disorders.

SOIL TREATMENT TO CORRECT TIPBURN DAMAGE

Mr. Ridgeway followed the suggestion of applying thirty pounds of borax per acre in the greenhouse unit in which tipburn had appeared the worst. Ordinarily three crops of lettuce are grown each year from September 1 to May 1. The borax was applied ahead of the second planting. The results of this simple and single treatment were phenomenal. At harvest time, the total yield was estimated to have increased from ten tons to twenty tons per acre for a single crop. The leaves held their normal green color throughout harvest, without even a trace of tipburn. The plant sap did not flow as freely in cutting and there was an absence of the metallic sound in handling.

The soil in this greenhouse has been used continuously for more than thirty years. It is a highly weathered type common to southern Illinois and is one expected to be low in available boron for alfalfa and other legume crops. Previous to 1935 manure from the livestock yards in East St. Louis had been applied at the rate of one hundred tons per acre. For the last ten years manure produced on the home farm had been used. Since the farm soil is probably low in available boron, the feeds produced and fed to the livestock are likewise low. Intensive use of the greenhouse soil, including three crops of lettuce yielding fifty to sixty tons per acre and one of tomatoes yielding from twenty to thirty tons, had undoubtedly caused a heavy withdrawal of available boron so that a deficiency for lettuce was created. No apparent nutritional disorder has been observed with tomatoes that might be attributed to boron deficiency.

Mr. E. J. L. Larimer, a neighbor of Mr. Ridgeway, also reported correcting tipburn damage in leaf lettuce by using thirty pounds of borax per acre.

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ANTHROPOLOGY

BISON IN ILLINOIS ARCHAEOLOGY

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This paper presents a review of archaeological evidence of the bison in Illinois in hope that it may elucidate certain problems of culture history and animal geography. As long ago as 1875 both J. A. Allen and N. S. Shaler pointed out that the "Mound Builders" apparently did not know the bison. Shaler postulated that the "Mound Builders" were too late to have encountered extinct forms of bison and had disappeared before the modern bison came into the area. Shaler further thought that the modern Indians who followed the "Mound Builders" had extended the limits of the treeless plains eastward by burning the land over and thus permitted the modern bison to enter the region. Otis Mason in 1895 questioned Shaler's statements. He asked first if it were true that the "Mound Builders" did not know the bison, and, secondly, if this were true, then did the bison cross the Mississippi after the "Mound Builders" disappeared, or was the appearance of the bison the cause of the decline of the "Mound Builders".

This problem could not be answered until the sequence of archaeological cultures had been established and some of their relationships had been clarified. The advances which have been made in Midwestern archaeology since these men wrote make it possible to reexamine the problem of the bison.

THE BISON EAST OF THE MISSISSIPPI

The range of the bison in the eastern United States in early historic times provides one set of data. J. A. Allen (1875) has summarized this historical evidence and concludes that the bison east of the Mississippi was restricted largely to the areas drained by the Ohio and Illinois rivers and their tributaries. It was particularly numerous over the prairies of Illinois and Indiana and the country immediately bordering the Ohio and its upper tributaries. "Its range was hence restricted to the prairies, the scantily wooded districts, and the narrow belts of open land along the streams." (Allen, 1875, p. 115.)

Marquette, Marest, and Charlevoix, among others of the early French explorers, note both the presence of the bison in Illinois and its use by the Illinois Indians. As late as 1773 it was abundant along the Kaskaskia and Illinois rivers, but soon thereafter began to disappear rapidly, so that by 1800, according to Allen, not a bison remained east of the Mississippi south of the Iowa-Minnesota line.

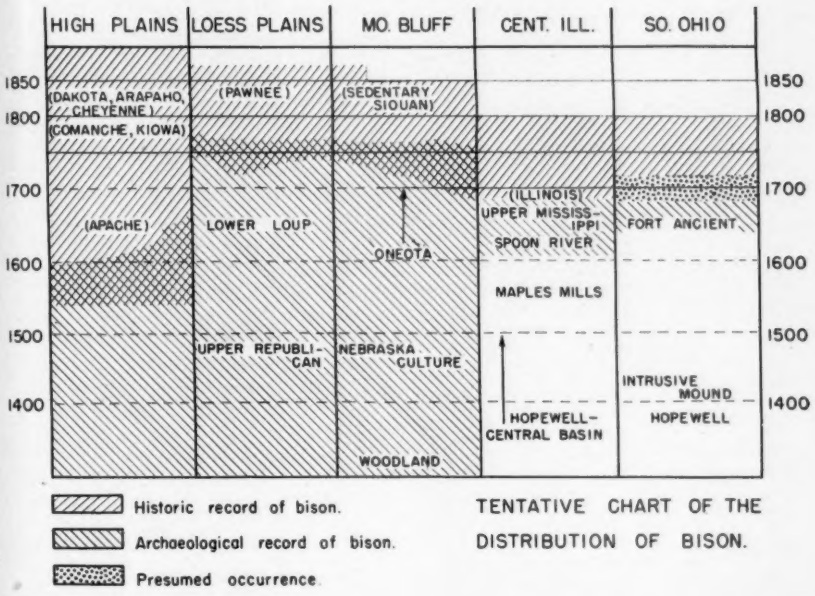
The presence of the bison and information concerning its disappearance are established from history,

TABULATION OF BISON REMAINS FROM SITES IN ILLINOIS

Site	Culture	Notes on Bison	Reference
Abbott Mound #2 Scott Co.	Hopewell and Historic	3 molars, association uncertain	Baker (1941), p. 74.
Tr1, Clear Lake Tazewell Co.	Hopewell, Spoon River and Maples Mills	ca. 19 specimens Spoon River	Cole & Deuel (1937), p. 266 Schoenbeck (1942) and (1944).
Crable Site Fulton Co.	Spoon River and Oneota	remains including skull Spoon River-Oneota	Smith (1943), also unpublished data.
Fo12 Fulton Co.	Central Basin and traces of Maples Mills and Middle Mississippi	2 specimens, association uncertain	Cole & Deuel (1937), pp. 102-106, 266.
Fo680 Fulton Co.	Woodland burials and Mississippi occupation	1 specimen, with Mississippian	Ibid., pp. 106-108, 266.
Fo14 Fulton Co.	Red Ochre, Central Basin and Mississippian	2 specimens, in Mississippi refuse	Ibid., pp. 75-94, 266.
Fr35 Fulton Co..	Central Basin and Spoon River	1 specimen, probably in Mississippi refuse	Ibid., pp. 126-131, 266.
Fr49, Whitnah Fulton Co.	Hopewell and scattered Mississippian	1 specimen, association uncertain	Ibid., pp. 161-166, 266.
Fr574, Hummel Fulton Co.	Hopewell	1 specimen	Ibid., pp. 166-171, 266.
Kingston Lake Peoria Co.	Spoon River and Maples Mills	ca. 7 specimens Spoon River	Simpson (1939) Baker (1941), p. 74.
Plum Island LaSalle Co.	Upper Mississippi	1 molar in a pit	Baker (1941), p. 74.
Fisher Site Will Co.	Upper Mississippi, late Woodland & historic	humerus with burial of Upper Mississippi or Late Woodland	Unpublished Mss. of George Langford

but for information concerning its time of arrival we must turn to archaeology. Remains of the bison have been discovered in a number of sites in Illinois, and a tabulation of the major occurrences accompanies this paper. This table lists site and county, archaeological manifestations present at the site, number of specimens and where possible their association, and the references from which the data were derived. All twelve sites given in the table occur in counties bordering the Illinois River where we know the bison was abundant in early historic times. This point is not in itself significant, however, due to the paucity of faunal data from other parts of the state. The second point immediately apparent from the table is that in almost every instance the bison bones were discovered in sites showing Mississippian manifestations. The only exception is the Hummel village site in Fulton County which shows a homogeneous Hopewell occupation according to Cole and Deuel (1937, p. 167). In several other instances it was not specifically stated from which of several occupations the bones came, but internal evidence in most of these cases suggests that it was either a Mississippian or Maples Mills manifestation. On the other hand, the Mississippian sites reported by Cole and Deuel which did not show the bison were represented by small collections and do not conclusively indicate that the animal was not present. In general, then, the bison in Illinois would seem to correlate with the Mississippian manifestations.

Tabulation of other areas of the



TENTATIVE CHART OF THE DISTRIBUTION OF BISON.

eastern United States has not been attempted because of inadequate reports of faunal remains of archaeological sites. This inadequacy largely results from a tendency on the part of archaeologists to have the faunal remains reported for the total site without regard to their stratigraphic occurrence.

Some comparative material is, however, available. J. B. Griffin (1943, p. 374) has published a table of faunal remains of sites of the Fort Ancient Aspect in Ohio and adjacent states. Of all these sites, the bison appears only at Madisonville and, questionably, at Anderson. In another place (p. 124) he notes that Willoughby reported finding some sixty to seventy beamers of bison bone at Madisonville. Myer (1928, pp. 608-609) notes specifically that he found no bison bones in the several hundred village sites he explored in Tennessee, and particularly, that he found none at the Gordon and Fewkes sites, which are now classified into the Gordon-Fewkes aspect of the Middle Mississippi phase. Meyer (1928, p. 555) postulates that the bison had not yet arrived in Tennessee at the time these sites were occupied, but had arrived in Ohio by the time Madisonville was occupied.

West of the Mississippi, bison bones are found in archaeological horizons ranging much farther back in time, but no detailed citations are deemed necessary in the present paper. The accompanying chart of the distribution of bison shows tentatively the range of the bison through time in several regions both east and west of the Mississippi, based on both historical and archaeological documents. The culture sequences, and to a considerable ex-

tent the dating, are taken from Ford and Willey (1941) and Wedel (1940). It will be noted that the occurrence of the bison east of the Mississippi appears as a late spread of relatively brief duration associated primarily with Mississippian cultural manifestations.

CULTURAL IMPLICATIONS

Certain of the sites used in the tabulation of bison remains in Illinois belong to the Upper Mississippi phase, and constitute the latest known archaeological horizon in Illinois. Many lines of evidence favor dating this horizon from 1650 to 1700. The sites show some variation from one another and may in fact represent a time span; the earlier sites such as those in Jo Daviess County (Bennett, 1945) being transitional, and later sites such as Crable being a period of direct contact with other fully developed Oneota-like cultures (Smith, 1943). The time span would not be much more than fifty years in any case.

All of these local manifestations of Upper Mississippi in Illinois exhibit traits which seem related to the Oneota complex of the Central Plains, and the sites fall in the same time period. Since many of the traits which characterize this late horizon have a long history in the Plains, it seems plausible to assume that these traits were introduced from the Plains into the Illinois country. Wray and Smith (1943) have hypothecated such an eastward extension of Upper Mississippi, and particularly Oneota, traits in their reconstruction of the protohistoric period in Illinois. The proposed identification of Upper Mississippi cultures in Illinois with the Illinois tribes of the early contact period is based on the assumption that the preceeding Middle Mississippi horizon with horticultural economy was disrupted by several factors and replaced by Upper Mississippi cultures derived from west of the Mississippi. This interpretation seems to be strengthened by the evidence of the migration of the bison into the Illinois region at the time period under consideration. This would provide the economic basis for a new cultural development.

A clue to this spread eastward of Plains culture is to be found in Waldo Wedel's synthesis of Plains archaeology (Wedel, 1942). He places the Oneota, Loup River and Painted Creek manifestations in the protohistoric horizon, dating between 1600 and 1700. He hypothecates a general shift for this period from a horticultural economy with sedentary village life to a combined horticulture and bison hunting economy. This constitutes a reversion to the older hunting tradition which antedates the extension of Mississippi valley agriculture into the Plains. The villages of the period are fewer in number, but large and compact, and give evidence of the revival of old hunting techniques. Wedel interprets this change as the beginning of the Plains hunting economy as it is known in historic times, when it is characterized by the horse and firearms in the extensive exploitation of the bison herds. Since the horse and firearms are lacking in this protohistoric period, some other factor must be brought in to account for the abandonment of agriculture in favor of hunting. Wedel suggests that a period of drought in the Plains could have forced the village horticulturists to revert in part to nomadism.

The apparent coincidence of the appearance of the bison in Illinois with the adoption of a culture related to that of the Plains suggests that the emergence of Upper Mississippi complexes east of the Mississippi

river is in part a reflection of a change in basic economy. It may be stated as an hypothesis that the replacement of Middle Mississippi horticultural villages by Upper Mississippi villages with mixed horticulture and hunting economies represents the same shift which occurred at the same time in the Central Plains. This shift in economy brought with it the adoption of cultural patterns which had been developed around bison hunting in the Plains. Thus the spread of the bison east of the Mississippi, plus a disruption of village life in the Plains (and possibly in Illinois as well) by drought resulted in the replacement over a large area of horticultural groups by semi-nomadic hunting economies, with basically similar cultural complexes.

The spread of the bison which has been assumed here seems to be indicated by several bits of evidence. The lateness of arrival in Illinois appears substantiated by the archaeological occurences of bison remains. The sites which belong to the Upper Mississippi horizon are without exception located in the northern part of the state, which constitutes an extension of open prairie similar to that found in Iowa and eastern Nebraska. This prairie is ecologically identical with the Plains, which formed the natural habitat of the bison. Why the bison did not enter this region in earlier times is a problem which can only be raised and not answered at present. Possibly the droughts on the Plains forced the bison to migrate to adjacent regions which might offer better grazing.

CONCLUSION

In summary, the following tentative conclusions may be drawn. The bison appeared east of the Mississippi in large numbers no earlier than 1600 and became extinct in this area by 1800. The cause of this migration is probably to be found in a period of drought which forced the bison to seek better grazing land. The same period of drought may well have been responsible for the partial abandonment of horticulture by the aborigines at this same time. The cultural manifestations which emerge in this protohistoric period are closely related in the Plains and in the Illinois prairie land. This similarity may be interpreted as the result of the adoption of a common type of mixed horticultural-bison hunting economy, with the diffusion from the Plains of a culture complex built around this economy. The spread of this Plains culture into Illinois was facilitated by the disruption of the settled horticultural economy of the preceeding period.

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BOTANY

DEVELOPMENT OF SEEDS AND EMBRYOS IN *PINUS PONDEROSA*, WITH SPECIAL REFERENCE TO SEED SIZE

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INTRODUCTION

This investigation was begun in the summer of 1942 while the senior author was a visiting investigator at the Placerville Laboratory of the Institute of Forest Genetics. The material discussed in the first part, concerning seed size and cone size, was all obtained and tabulated at Placerville, California. Toward this part of the investigation the Institute furnished considerable help at the time of collection, in the climbing of trees and opening of the cones, including the time of a number of persons during several days. The dissections and measurements on the embryos of three of the trees (15-43, 3-14, 3-57) were also completed at that time. The data for tree 3-56 were obtained in part. The junior author has completed additional dissections and measurements on the seeds of tree 3-56 and all of the data on embryos of trees 3-40 and 3-52, work which was carried out at the University of Illinois on the seeds preserved in 1942. It is therefore appropriate to express thanks to the Institute for the facilities of their laboratories and for the cooperation of Mr. W. C. Cumming and many others employed at the Institute, which made this investigation possible on a scale that included more than 100 seed cones.

The western yellow pine, *Pinus ponderosa*, Lam., is an important timber tree occurring throughout the western part of the United States, from the Black Hills, Great Plains, and Rocky Mountains to the Pacific Coast. The Californian form of this tree is typical of this species and is more robust than the variety *scopulorum* Engelm. which occurs in the Rocky Mountains east of the Sierras. This latter variety is very similar to the typical form of the species, but somewhat smaller in all of its parts. The variety *scopulorum* may therefore be expected to have seeds that would average somewhat smaller.

In California, where this investigation applies, the ponderosa pine has a wide distribution. On the west slope of the Sierra Nevada, the species is noted for its wide altitudinal range. The Institute of Forest Genetics has experimental plots near Sacramento at altitudes of 185 and 350 feet with many other plots distributed between these and the station at Placerville which is at 2740 feet. Eastward, the trees occur at elevations up to 6,900 feet near Lake Tahoe. There are not many species of plants that occupy a larger area of distribution both geographic and altitudinal.

Within the area of a single site,

trees may be found that possess cones more than 5 inches long whereas in other trees the cones may be less than three inches in length. There has been an impression, supported by a few records in the literature, that large cones usually possess large seeds and that small cones usually have small seeds, but there seemed to be no records based upon individual cones. By the methods usually employed in harvesting the seed crop, the cones of all sizes from the same tree are massed together. There are many records at the Institute showing that large, medium, or small seeds have been obtained from individual trees, but it was not possible to know how much correlation may be found among seeds from cones of various sizes coming from a single tree. In connection with an effort to obtain embryos in developing stages from large vs. small seeds it happened that a large number of cones were harvested and measured during the early part of August 1942. The seeds of these contained embryos that were only about half developed, but the cones and their seeds had grown to their ultimate size more than a month earlier. The seeds possessed stony seed coats and could be handled in the same manner as fully ripe seeds, except that at this stage the cones had to be cut open by hand, the seeds carefully removed, sorted for size and kept from drying out.

Pine seeds, like those of most gymnosperms, are full grown at the time of fertilization. Fertilization occurs in nearly all pines 13-14 months after pollination. They are considered biennial, since two growing seasons are required to mature a seed crop. The only known exceptions to this are a few triennial species, for example *Pinus pinea* L. from northern Italy and *Pinus leiophylla* Schlecht. and Cham. from southern Mexico, which are not closely related taxonomically. These require about 25-26 months between pollination and fertilization.

The cones of biennial pines enlarge only slightly after pollination during the first season and remain small throughout the ensuing winter. With the opening of the buds in the following spring these year-old conelets experience their grand period of growth, enlarging rapidly to their full size within a period of less than six weeks. Hence the cones are full grown, though still somewhat succulent at the time of fertilization about the end of June or early in July; a month later the cones have become hard and woody, and they may remain green for weeks after the seeds are fully matured.

After fertilization there is no appreciable increase in the size of the ovules or seeds so that a seed in which fertilization has failed to take place remains as a full sized empty seed, in which the stony seed coat may be as fully developed as in a sound seed. Morphologists who have prepared pine ovules for microscopic examinations know that the seed coats begin to become so stony a few days after fertilization that it is very difficult, sometimes impossible to cut sections without first removing the seed coat in preparation for killing and fixing material that is to be sectioned.

The present study is concerned with seeds about a month or six weeks after fertilization, when the embryos, now about half developed, are beginning to differentiate stem tips and cotyledons. Since the seed coats had become fully thickened and hardened the seeds could be graded rapidly by passing them through screens of known gauge.

More than 25 years ago, the senior author (3) described the embryo-

geny of pine. This study was based upon the Jack pine and the Austrian pine. Since that time the embryology of more than 24 different species of pines, representing nearly all sections of the genus, has been examined. All of them agree in the essentials of embryological development. All pines have cleavage polyembryony (6). Eight embryos may result from each egg that is fertilized. The numerous embryos remain small for about 3-4 weeks. They compete in their development until one of them gains supremacy, shown by its larger size and forward position. This selected embryo enlarges to form the embryo with stem tip and cotyledons, which remains in the seed at maturity, while the great majority of the other similar embryonic units grow more slowly and finally cease to grow altogether, seldom reaching the stage in which these organs appear.

The stages of the embryos desired for the present investigation were these later ones, near the time when the root, stem tips, and cotyledons are forming, or have become fully differentiated. At this time the surviving embryos are growing rapidly. These stages were made the subject of a special study described in the later portion of this paper. The results of the first part of this study deal chiefly with the relation of seed size to the size of the cone and with records as to the proportion of sound seeds and empty ones that could be detected at this time.

From the standpoint of seed size there is little difference whether the seeds are collected in August or in October when the seeds are ripe. It is likely that dry ripe seeds would tend to be slightly smaller due to loss of imbibitional water. Certainly they would not be larger. The endosperm which surrounds the embryo throughout its period of development would be filled with food reserves so they may be heavier at ripeness.

The trees used were marked seed trees, most of them situated near the site of Sportsman's Hall, eleven miles east of Placerville along U. S. Highway 50 at an elevation of 3700 feet. The seeds from several other trees were included, one from the grounds of the Institute of Forest Genetics at an elevation of 2740 feet, also a few trees from another site 32 miles east of Placerville at an elevation of 4100 feet. Some of these seed trees were so tall that cones could be reached only by climbing with rope; others were small enough so that the most of the cones could be reached with little climbing or from the ground. Records of the Institute had indicated that large, medium or small sized seeds had been obtained from these particular trees that had been selected and marked with numbers, in investigations several years earlier involving certain progeny tests carried out at the Institute.

In general the seeds were found to belong to the size groups that had been recorded previously from the trees. Pollination of the trees in the previous season had been fairly successful. There were a few cones that showed some insect damage. This was only a fair cone year in ponderosa pine; it was not one of the best cone years. The cones of 1942 were much better than in the year 1944, when many of them were heavily infested with seed chalcids—*Megastigmus albifrons* Walk. The seeds of open wind-pollinated cones of tree 4B-56 were so badly infested with this insect in 1944 that no healthy seeds with embryos were found; only a few in the cones covered by bags.

The screens used in separating the seeds mechanically were standard screens employed as interchangeable parts in a small separator of the kind used for cleaning seeds at experiment stations. These screens consisted of framed metal sheets with round openings of various sizes ranging from No. 7 to 20, in which the number indicates the diameter of the openings in steps of 64th of an inch. Thus the openings of No. 14 screen are 14/64ths of an inch in diameter, a No. 14 seed is one that will pass through this opening but not through the smaller No. 13 screen with 13/64th inch openings.

The sizes of these openings, converted into metric units are as follows: No. 10 openings are 3.97 mm. in diameter; No. 11 = 4.37 mm.; No. 12 = 4.76 mm.; No. 13 = 5.16 mm.; No. 14 = 5.56 mm.; No. 15 = 5.95 mm.; No. 16 = 6.35 mm.; No. 17 = 6.75 mm.; No. 18 =7.14 mm.

I. RELATION BETWEEN CONE SIZE AND SIZE OF SEED

The following tables give the results of this study tabulated according to cone length. Defective seeds that were discarded (some of them only partially enlarged, others full sized, but obviously defective) were recorded in the columns to the right. The partially enlarged ovules became aborted before fertilization. There were still many ovules that had not begun to enlarge, which are disregarded. As is well known, the maximum potential output of 2 seeds per scale is not attained. Other obviously defective or insect damaged seeds even if they were full grown, were discarded and appear only in the column at the right, not among the seed output of the cones.

Each size of seed from the same tree was placed in preservative for future study. This preserving solution (FAA) contained about 50 percent alcohol. In this lower specific gravity the sound seeds sank whereas many defective empty seeds usually floated and could be separated easily, with a cutting test applied whenever in doubt, so that there would be no error in unintentionally discarding seeds with embryos. However among the heavier seeds there were still many that were found to be defective upon dissection in later studies. The discarded floating seeds, not separated individually by cones are shown as without embryos below, in the column showing individual seeds sizes. Where seeds were actually dissected later, this corrected entry of seeds without embryos was made for the total seeds of some of these trees. The embryos of the seeds of some of these trees still remain to be dissected. The first number of the tree is the plot number, the second the individual tree number. Thus 3-14 is tree No. 14 in plot 3.

In connection with the dissections of the embryos from the seeds, a number of these seeds were measured individually with micrometer calipers for length. It was found that each size class included seeds of the same length as others in the nearest size class, but the mean lengths were distinct. Measurements on 20 No. 10 seeds from tree 15-43 gave a mean length of 5.21 mm.; 14 No. 11 seeds gave a mean length of 5.75 mm.; 37 No. 12 seeds gave a mean length of 6.18 mm.; 42 No. 13 seeds gave a mean length of 6.64 mm.; 26 No. 14 seeds gave a mean length of 6.97 mm.; 15 No. 15 seeds gave a mean length of 7.01 mm. The last group of No. 15 seeds is probably not representative of this size class since this group, near the upper limit, did not include many of the largest seeds that would pass through No. 15 openings.

Another set of seed samples was measured from tree 3-38. These seeds were somewhat longer, especially in the larges sizes. Measurements of 20 No. 12 seeds gave a mean length of 6.89 mm.; 32 No. 13 seeds gave a mean length of 7.41 mm.; 34 No. 14 seeds gave a mean length of 8.31 mm., 40 No. 15 seeds gave a mean length of 8.74 mm.; 34 No. 16 seeds gave a mean length of 9.16 mm.; 30 No. 17 seeds gave a mean length of 9.30 mm.; 20 No. 18 seeds gave a mean length of 9.67 mm. The standard deviation of each size class might seem of interest, yet this calculation throughout the series does not seem justified. This value would be relatively large and nearly the same for all seed sizes. The standard deviation of length for No. 15 seeds of tree 3-38 is 0.37 mm.

It has been the belief of many that seed size is an indication of vigor in the plant that results from the seed. Records, such as those of Eliason and Heit (8) indicate this, but the differences are not significant by statistical standards. There can be no question about a large seed giving the seedling a better start than a small seed, others things being equal.

A larger seed contains a larger embryo as well as more endosperm with stored food. Large seeds usually germinate more rapidly and the seedlings grow faster in the first months. However other things, such as the inherent vigor of the embryo contained in the seed, are usually not equal. Righter (12) has shown, for example, that the seedlings possessing greater inherent vigor due to their hybrid genetic constitution will soon outgrow the non-hybrid seedlings even if they originate from a smaller seed.

It may be pointed out here that while the seeds of some angiosperms may actually become larger when they contain a more vigorous embryo than other seeds with less vigorous embryos, the situation is different in gymnosperms. In pines for example the seeds are full grown before fertilization takes place. They have hardened stony seed coats long before the embryo is visible to the naked eye and cannot yield to the growth pressure or other stimulus of a more vigorous embryo. As pointed out in the opening paragraphs, the abortive seeds in which fertilization has not taken place may be fully as large as those which are healthy seeds.

Most of these collections of cones were made at random—trees 3-6, 3-8, 3-10, 3-14, 3-38, 3-52, 3-55, and 3-56. The trees themselves were selected because they had been used in previous investigations and records of the size of the seeds were available, but the cones selected from these trees were taken by chance.

The large cones of trees 3-38 (m= 5.36 inches) and 3-40 (m = 4.62 in.) yielded large seeds; those of trees 3-7 (m = 3.87 in.) 3-52 (m = 4.08 in.) and 3-55 (m = 4.08 in.) yielded small seeds. However tree 3-8 with large cones (m = 5.25 in.) had medium sized seeds, very comparable to tree 4B-53 in which cones were only 3.37 inches long. To the extent that this limited survey shows anything, there are indications that seed size and cone size are not very closely correlated and that individual trees differ. Some of the largest seeds were taken from tree 3-14 having a mean cone length of only 4.34 inches. This was a tree that had been classified as large seeded in previous years. Unless the mean length of cones changes gradually with the age of the tree, one may expect this tree to have cones of medium length with large seeds in future years, and that the large cones of tree 3-38 will continue to be

large and have large seeds. No doubt in certain years, the cones of all trees, probably also the seeds, would fall below their respective means or go higher, since seasonal conditions may affect all trees adversely or favorably.

Some of the trees such as 3-3 and 3-55 failed to show any correlation of seed size with cone size. Tree 3-40 appears to show a trend in the opposite direction, with a larger proportion of the larger seeds in the smallest cones. However tree 3-14 shows a definite trend in having more large seeds in the largest cones that were measured. The majority of the trees showed a similar trend.

From the literature on the subject there are a number of records that show the same general condition. Eliason and Heit (8), Munns (11) and several other investigators cited by Baldwin (2) indicate that large cones tend to have larger seeds than small cones, in pines and other conifers. In comparing the results of these records, one would come to believe that the tendency to find large seeds in large cones is less marked in *Pinus ponderosa* than in other species.

The records of Aldrich-Blake (1) give the weight distribution of the seeds from the cones of the Corsican pine—a variety under *Pinus nigra* Arn. In the examples from Aldrich-Blake, especially those tabulated by Righter (12), cones 3.5-4 cm. long have seeds ranging in weight from 6-7 milligrams to 16-17 mg., while the cones (from the same tree) that were 7-7.5 cm. long had seeds weighing between 11-12 and 28-29 mg. The mode of the seed weight in the small cones was 10-11 mg.; that of the large cones 22-23 mg. This is probably the most accurate record available for comparison.

One may gain an approximate basis of comparison by calculating the relative weights of the seeds on the basis of their volume. A pine seed is a flattened ovoidellipsoid. It is known from solid geometry that the volume of a series of similar bodies is proportional to the cube of any of the homologous dimensions, such as the length, width or thickness. Hence, the volumes of seeds of similar shape in a series of sizes may be compared. If the volume of No. 10 seed is taken as unity, that of No. 12 is 1.7 times the volume of a No. 10 seed, that of No. 16 is 4.14 times and a No. 18 seed is 5.85 times that of a No. 10 seed. Aldrich-Blake's largest seeds are slightly more than four times as heavy as his smallest seeds. The range of sizes included in the weight classes which he gives are therefore equivalent to the range between No. 10 and No. 16 seeds; they are slightly below the range between No. 11 and No. 18 seeds shown by tree 3-38.

These comparisons are all relative. The actual sizes of the seeds of *Pinus nigra* ranged between No. 8 and No. 11 on trees which we have had occasion to measure with screens, and it is likely that the precise variety of this species differed. However the seeds of *P. nigra* have a slightly different shape from those of *P. pondersosa;* they are somewhat longer in proportion to the width.

The corresponding differences in sizes of the cones of all of the series *Pinus ponderosa* is less than that shown for the Corsican pine. This comparison seems to show that our seeds include a range of seed sizes from single trees with about the same spread as the data of Aldrich-Blake, about two of whose lowest weight classes would be equivalent to the steps between No. 10 and 11 seeds while about 8-10 or more of his

higher weight classes would be included in the size range between Nos. 15, 16, and 17 seeds.

McIntyre (9) has described the sizes of the cones matured in 1927 in *Pinus pungens* on trees of various ages, including some of the first cones, matured on a tree 7 years old; others from trees having ages at intervals of several years up to 18. His tabulation shows, aside from the number of seeds per cone scale, their distribution within the cone and the number of abortive seeds. The length of the cones varies from tree to tree in this particular year and the number of viable seeds appears to be closely correlated. Although McIntyre gives nothing concerning the sizes of the individual seeds from the different cones with which our data on seed size may be compared, his record includes the data on the total number of viable seeds from an uninterrupted series of the serotinous cones of this species produced over a 9 year period. This record seems to bear out the thesis that over a period of years the size of the cone and seed yield on a given tree remains about the same in spite of wide fluctuations in certain years which might be recorded in other species as good or bad cone years.

The cones of any given tree appear to show some correlation between cone size and seed size. The range in sizes of cones from individual trees in the first set of random collections were not great enough to provide desirable extremes for studies of cone and seed sizes in individual trees, though they show definite trends as indicated above. Consequently another collection was made a few days later, at a higher altitude, so that the embryos would also be found in the desired stages for study. These are shown in trees 15-43 and 15-78 from trees at 4100 feet. Here an effort was made to include the widest possible range in the sizes of the cones. From tree 15-43 there were cones 2.6-5 inches long; from tree 15-78 they were 5-6 inches long. Here several small cones less than 4 inches long had a large increase in seeds of the smallest sizes, a very large proportion of which were without embryos. However the largest cones from tree 15-78 did not contain seeds that were as much larger than the average as their large size would suggest.

The small amount of definite data shown here would seem to justify the conclusion that on a given tree the large cones would probably have larger seeds than the small cones. Between different trees of *Pinus ponderosa*, the largest seeds may be found in large cones or cones of about average size, seldom in the smallest, while the smallest seeds may be found in cones of average size or in the smallest cones, but usually not in the largest.

Complete records similar to those of McIntyre, Aldrich-Blake and those we are presenting in our tables serve to show the extreme complexity of the problems of seed production in pines. Pollination must be fairly good or the conelets will drop off in the first year, but even if they are retained and enlarge in the second season many of the ovules may fail to enlarge to form seeds. Presumably, these were not pollinated, but this early abortion of half grown ovules may include some that received pollen which failed in germination. If the ovules become full grown fertilization may still fail in many of them. These remain as full sized empty seeds. If fertilization actually takes place there are many embryos that compete with each other for about a month. Finally those that form cotyledons in the embryos about a month or 6 weeks

old may develop fully as embryos of seeds. Then and then only does the viable seed arrive, provided that the season is not too short, as in very high altitudes, so that the embryos may reach sufficient maturity within the seeds to germinate. Throughout the period of development of the embryos there may be other losses through death of the embryos.

TABLE 1.—SIZES OF SEEDS OF PINUS PONDEROSA
Tree 3-56, collected Aug. 5, 8 and 12. Elevation 3700 ft.

Cone length (in.)	Seed sizes by screen openings[1]									Half grown and defective
	10	11	12	13	14	15	16	17	Total	
m = 3.28										
3	....	3	16	14	....	....	....	....	33	10
3	....	53	10	2	....	....	....	....	65	5
3	....	11	18	2	....	....	....	....	31	17
3	5	30	22	3	....	....	....	....	60	4
3.12	....	12	18	5	....	....	....	....	35	26
3.25	....	45	28	....	....	....	....	....	73	0
3.25	....	8	29	9	....	....	....	....	46	4
3.25	....	14	20	4	....	....	....	....	38	13
3.25	5	11	27	14	4	....	....	....	61	11
3.25	....	4	27	19	....	....	....	....	50	13
3.37	....	2	9	22	9	....	....	....	42	16
3.37	....	35	51	....	....	....	....	....	86	6
3.50	....	8	41	27	....	....	....	....	76	10
3.50	....	5	23	34	2	....	....	....	64	12
3.63	4	15	48	40	....	....	....	....	107	0
3.75	....	6	40	34	2	....	....	....	82	20
Not. measured	....	9	30	11	....	....	....	....	50	0
Total	14	271	457	240	17	....	....	....	999	
No embryos (less)	9	112	198	88	7	....	....	....	405	40%
Net good seeds	5	159	259	152	10				494	60%
Embs. dissected	5	94	144	62	0	(Not all dissected)				

[1] Screen sizes in millimeters:
No. 10 = 3.97, 11 = 4.37; No. 12 = 4.76, 13 = 5.16; No. 14 = 5.56, 15 = 5.95; No. 16 = 6.35, 17 = 6.75, 18 = 7.14

Tree 3-52, collected Aug. 5, 1942. Elevation 3700 ft.

m = 4.62										
4.0	18	22	....	....	....	....	....	....	40	31
4.5	5	21	31	....	....	....	....	....	57	12
4.62	2	9	8	....	....	....	....	....	19	22
4.75	14	22	3	....	....	....	....	....	39	74
4.87	3	14	72	6	....	....	....	....	95	5
5.0	2	12	15	2	....	....	....	....	31	34
Total	44	100	129	8	....	....	....	....	281	
No embryos	38	78	89	7	....	....	....	....	212	75%
Good seeds	6	22	40	1	....	....	....	....	69	25%

TABLE 1.—SIZES OF SEEDS OF PINUS PONDEROSA—Continued

Tree 3-10, collected Aug. 5, 1942. Elevation 3700 ft.

Cone length (in.)	Seed sizes by screen openings[1]										Half grown and defective
	10	11	12	13	14	15	16	17	18	Total	
m = 4.57											
3.87	....	....	....	30	21	5	....	....	....	56	16
4.0	....	....	1	23	23	9	....	....	....	56	4
4.5	....	....	....	32	57	16	....	....	....	105	12
4.75	....	....	....	8	37	48	1	....	....	94	6
5.0	....	....	....	7	43	32	....	....	....	82	6
5.25	....	....	....	13	46	35	....	....	....	94	0
Total	....	....	1	113	227	145	1	....	....	487	
No embryos	....	....	....	9	33	20	....	....	....	62	13%
Presumed good seeds	....	....	1	104	194	125	1	....	....	425	87%

Tree 15-43, collected Aug. 15, 1942. Elevation 4100 ft.

m = 3.94											
Small, not measured	....	4	25	36	8	....	....	....	....	73	0
2.62	53	10	3	....	....	....	....	....	....	66	11
3.0	11	21	20	3	....	....	....	....	....	55	12
4.0	....	....	4	10	13	7	....	....	....	34	29
4.5	....	....	1	22	23	5	....	....	....	51	25
4.5	....	....	....	21	22	6	....	....	....	49	16
5.0	....	....	3	38	27	11	....	....	....	79	31
Total	64	35	56	130	93	29	....	....	....	407	
No embryos	52	23	29	46	46	15	....	....	....	211	51%
Good seeds	12	12	27	84	47	14	....	....	....	196	49%

Tree 15-78, collected Aug. 15, 1942. Elevation 4100 ft.

m = 5.56											
5.0	....	2	0	9	3	....	....	....	....	14	56
5.0	....	1	7	23	1	1	....	....	....	33	52
5.62	....	2	0	16	12	2	....	....	....	32	10
5.75	....	2	15	18	3	....	....	....	....	38	10
6.0	....	1	5	11	5	....	....	....	....	22	55
6.0	....	3	5	21	1	....	....	....	....	30	67
6.1	....	....	2	12	12	7	....	....	....	33	?
Total	....	11	34	110	37	10	....	....	....	202	
No embryos	....	8	16	52	19	6	....	....	....	101	50%
Presumed good seeds	....	3	18	58	18	4	....	....	....	101	50%

TABLE 1.—SIZES OF SEEDS OF PINUS PONDEROSA—Continued

Tree 3-38, collected Aug. 5, 8, and 12, 1942. Elevation 3700 ft.

Cone length (in.)	Seed sizes by screen openings[1]										Half grown and defective
	10	11	12	13	14	15	16	17	18	Total	
m = 5.36											
5.0	....	....	3	19	48	27	7	4	....	108	31
5.0	....	....	....	....	5	12	35	23	....	75	41
5.12	....	....	1	4	6	30	53	3	....	97	13
5.25	....	....	....	1	7	15	34	28	2	87	?
5.25	....	....	3	12	24	37	29	4	....	109	16
5.25	....	1	5	19	26	49	24	4	....	128	14
5.25	....	2	0	9	24	55	29	7	....	126	16
5.25	....	2	2	12	33	35	24	3	....	111	11
5.37	....	....	3	3	13	36	34	18	....	107	31
5.37	....	....	4	8	23	31	24	9	....	99	17
5.37	....	....	1	1	11	35	39	6	7	100	30
5.50	....	....	....	....	7	25	38	26	....	96	16
5.75	....	....	....	....	2	19	23	26	18	88	17
Total	....	5	22	88	229	406	393	161	27	1331	
No embryos	....	1	7	70	32	47	34	6	....	197	15%
Presumed good seeds	....	4	14	18	197	359	359	155	27	1134	85%

Tree 4B-53, collected July 11, 1942. Elevation 2740 ft. Stages I and II

m = 3.37											
3.25	....	....	3	9	16	11	....	....	....	39	14
3.50	....	2	17	25	10	5	1	....	....	60	15
Total	....	2	20	34	26	16	1	....	....	99	
No embryos	....	1	2	3	1	1	....	....	....	8	8%
Good seeds	....	1	18	31	25	15	1	....	....	91	92%

Tree 3-7, collected Aug. 5, 1942. Elevation 3700 ft.

Cone length (in.)	Seed sizes by screen openings[1]									Half grown and defective
	10	11	12	13	14	15	16	17	Total	
m = 3.87										
3.5	....	4	19	13	....	....	....	....	36	6
3.75	....	4	20	21	....	....	....	....	45	33
3.75	....	6	13	3	....	....	....	....	22	5
3.75	....	....	6	24	1	....	....	....	31	28
4.0	....	1	16	19	....	....	....	....	36	11
4.5	....	3	5	31	10	....	....	....	49	21
Total	....	18	79	111	11	....	....	....	219	
No embryos	....	2	22	16	1	....	....	....	41	19%
Good seeds	....	16	57	95	9	....	....	....	178	81%

TABLE 1.—SIZES OF SEEDS OF PINUS PONDEROSA—Continued

Tree 3-40, collected Aug. 5, 1942. Elevation 3700 ft.

Cone length (in.)	Seed sizes by screen openings[1]									Half grown and defective
	10	11	12	13	14	15	16	17	Total	
m = 4.63										
4	....	....	2	6	4	10	6	1	29	10
4.5	....	2	5	15	15	9	2	....	48	19
4.5	....	....	....	3	18	29	21	....	53	33
4.5	....	....	....	5	30	23	1	....	59	6
4.63	....	....	....	6	9	23	21	....	59	28
4.75	....	3	7	9	33	7	....	....	59	11
5.0	....	....	1	18	25	10	2	....	56	15
5.25	....	1	0	7	25	25	17	....	75	30
Total	....	6	15	69	159	136	52	1	438	
No embryos	....	6	9	24	80	59	22	1	201	41%
Good seeds	....	0	6	45	79	77	30	0	237	59%

Tree 3-14, collected Aug. 1 and 5, 1942. Elevation 3700 ft.

Cone length (in.)	Seed sizes by screen openings[1]										Half grown and defective
	10	11	12	13	14	15	16	17	18	Total	
m = 4.37											
3.5	....	....	....	7	10	9	....	....	....	26	14
3.75	....	....	....	....	20	25	10	5	....	60	9
4.5	....	....	4	12	22	12	14	....	....	64	?
4.75	....	....	....	1	12	19	16	12	....	60	15
5.37	....	....	....	....	5	34	33	17	6	95	49
Not measured	....	....	1	1	6	8	4	2	....	22	35
Not measured	....	....	....	....	3	24	17	5	....	49	31
Total	....	....	5	21	78	131	94	41	6	376	
No embryos	....	....	3	7	33	63	38	13	1	158	42%
Good seeds	....	....	2	14	45	68	56	28	5	218	58%

Tree 3-3, collected Aug. 12, 1942. Elevation 3700 ft.

m = 5.3											
5.0	....	....	2	22	33	22	2	....	....	81	7
5.25	....	....	5	23	43	6	....	....	....	77	22
6.25	....	....	....	48	22	10	1	....	....	81	3
Total	....	....	7	93	98	38	3	....	....	239	

TABLE 1.—SIZES OF SEEDS OF PINUS PONDEROSA—Concluded

Tree 3-55, collected Aug. 5, 1942. Elevation 3700 ft.

Cone length (in.)	Seed sizes by screen openings[1]										Half grown and defective
	10	11	12	13	14	15	16	17	18	Total	
m = 4.08											
3.62	....	6	1	4	3	....	....	....	....	14	3
4.0	....	6	22	13	....	....	....	....	....	41	23
4.0	....	1	1	3	2	....	....	....	....	7	15
4.12	....	9	20	21	....	....	....	....	....	50	20
4.37	....	3	5	28	....	....	....	....	....	36	21
4.37	....	8	11	40	3	....	....	....	....	62	25
Total	....	33	60	109	8	....	....	....	....	210	
No embryos	....	25	29	87	7	....	....	....	....	148	70%
Presumed good seeds	....	8	31	22	1	....	....	....	....	62	30%

Tree 3-6, collected Aug. 5 and 8, 1942. Elevation 3700 ft.

m = 4.8											
4.0	....	3	5	5	2	1	....	....	....	16	44
4.0	....	1	2	9	5	2	....	....	....	19	14
4.37	....	4	3	6	11	5	....	....	....	29	39
4.5	....	....	1	5	18	15	3	....	....	42	18
4.5	....	1	14	12	5	....	....	....	....	32	19
4.5	....	....	....	10	15	10	2	....	....	37	30
4.75	....	3	7	9	3	....	....	....	....	22	76
4.75	....	....	....	2	5	5	2	....	....	14	50
4.75	....	....	....	8	15	3	....	....	....	26	56
4.87	....	....	1	3	10	10	1	....	....	25	18
4.87	....	....	1	11	12	8	....	....	....	32	29
5.0	....	....	2	14	12	8	2	....	....	38	45
5.25	....	....	4	6	11	18	10	2	....	51	24
5.25	....	....	2	15	8	6	2	2	....	35	34
5.37	....	....	1	5	7	8	2	....	....	23	59
5.37	....	....	....	7	11	8	1	....	....	27	41
5.5	....	....	1	1	9	13	2	1	....	27	47
Total	....	12	44	128	159	120	27	5	....	495	
No embryos (less)	....	8	27	61	77	69	17	3	....	262	53%
Presumed good seeds	....	4	17	67	82	51	10	2	....	233	47%

Tree 3-8, collected Aug. 5, 1942. Elevation 3700 ft.

m = 5.25											
4.87	1	....	5	79	6	....	....	....	....	91	2
5.37	....	1	5	55	32	5	....	....	....	98	4
5.50	....	....	8	43	54	9	....	....	....	114	7
Total	1	1	18	177	92	14	....	....	....	303	
No embryos	....	....	10	67	18	3	....	....	....	98	32%
Presumed good seeds	1	1	8	110	74	11	....	....	....	205	68%

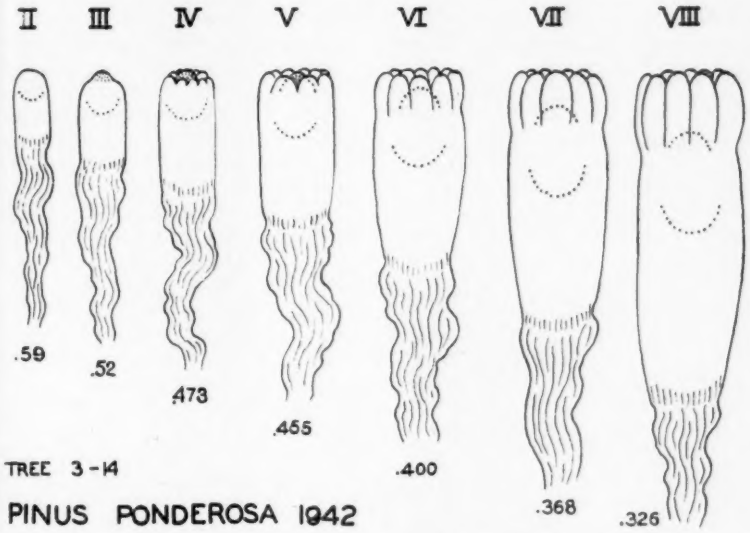

FIG. 1.—Embryos and parts of suspensors in various stages (X 12).

II. THE RELATION BETWEEN THE SIZE OF THE EMBRYO AT DIFFERENTIATION AND THE SIZE OF THE SEED.

Previous investigations on the embryos of the pine (3, 6) have been concerned very largely with the early stages of the embryogeny, the period during which embryonic selection (5) occurs. The later development of the embryo was described only in its broad outline. Some of the stages concerned here have been known for many years. They were illustrated or briefly described long ago by Strasburger (15-16) and others. Stages III and IV as defined in this paper, were illustrated by rather crude woodcuts in Schleiden's textbook more than a century ago. In the second edition of Schleiden (13) the illustrations of the embryo of a fir appears on page 373 of Part 2; his fig. 225A is an embryo in stage III, B an embryo in stage IV. Buchholz (3) in reviewing Schleiden's and other early contributions pointed out that at an earlier stage than these stages the plerome of the root tip becomes recognizable internally, shown in sections of the embryo. The order of appearance of these organs is: 1, root tip and root cap; 2, stem tip; 3, cotyledons.

Figure 1 shows a series of embryos of the pine in successive stages of development, drawn closely to the same scale, with the stages designated by the Roman numerals II-VIII. During stages I and II the embryo is composed of a cylindrical mass of dividing cells, rounded at the apex. At the base of the embryo successive layers of cells elongate to form a long suspensor of greatly elongated cells and the massive root cap that continues to give rise to additions to the suspensor. Only the

spherical area above the dotted line contributes to the embryo seen in a young seedling.

Stage III is reached when the stem tip primordium becomes visible as a special bulge at the end of the larger dome that terminates the upper end. This is the first change in the cylindrical embryo that is recognizable externally. As may be seen in the tables of measurements of embryos which follow, the actual dimension when this stage is reached differs considerably, depending upon the size of the seed. Under a binocular dissecting microscope this stem tip primordium has a striking appearance, due to a greater translucency at this point.

Schopf (13) in his detailed histological study of the embryo of Larix has designated the stages as pro-stage, meta-stage etc. Stage I would be included in the meta-stage. The greater part of stage II belongs to his ana-stage, but it is not certain how closely the end point of stage I would correspond to the end of meta-stage or how much of the ana-stage would be included in stage II. Stage III begins in the later portion of the ana-stage while the remaining stages III-VIII all belong to the telo-stage. These externally recognizable stages therefore appear to parallel some of Schopf's stages based upon internal anatomy, and the two systems are entirely consistent. Our stages represent subdivisions of his stages, mostly of his telo-stage. It was found necessary in dissecting large numbers of embryos from seeds of different sizes, to define a progressive system of morphological growth stages that could be recognized quickly by means of critera visible externally during dissection.

Stage IV is reached when the circle of cotyledonary primordia may be observed surrounding the stem tip on the shoulder of the embryo. The number of these primordia may usually be counted by tilting and rotating the embryo. As long as the cotyledons are small so that the stem tip protrudes beyond the length of the cotyledons the embryo is classified as belonging to stage IV.

Stage V includes embryos in which the cotyledons and stem tip are equal in length. This condition is easily recognized under the dissecting microscope, and may require some exercise of judgment only if the embryo is slightly asymmetrical.

Stage VI has cotyledons that are definitely longer than the stem tip, but less than twice as long. Usually the stem tip is still observable by tilting the embryo under the dissecting microscope even though this apical point is now overtopped on all sides by the cotyledons.

Stage VII is a stage older and larger than Stage VI in which the cotyledons are long enough to hide the stem tip completely from view. The upper dotted lines in these stages of figure 1 show the position of the stem tip. Stage VIII differs from stage VII only in the size of the embryo and in the relative length of the cotyledons. These last two stages are therefore somewhat arbitrarily separated from each other as size classes. The mean dimensions of stages VII and VIII might vary considerably in collections made from the same tree on different dates with a week between. In seeds that are fully ripe all embryos would be expected to be in stage VIII. Hence as ripeness is approached the mean dimensions for this stage would increase. On the other hand in seeds from cones that have a majority of their embryos in stages IV-VI the most mature embryos in some seeds belonging to stage VIII would fall far short of the dimensions observed later in the

ripe seeds. For this reason the embryos of stage VIII in some of the tables have been designated VIIIa.

Not all trees were found to have the embryos in their seeds in the same stages of development on August 5, the first date on which many cones were collected. The seeds of several of the trees were already too mature to include many of the cotyledon-forming stages. Some of these were sampled but the series was not dissected. The tables show that a few of the trees from which all embryos were dissected, were found to include too many embryos in the older stages. Other trees gave a very satisfactory distribution of stages in a single collection of cones obtained on the same or successive days. From several trees, in which sampling indicated that the embryos were mostly still in the earlier stages, a second collection was made 5-6 days later.

The advantages offered by the possibility of recognizing morphological growth stages without resort to sections are apparent, not only in the possibility of comparing steps of maturity in large seeds vs. small seeds, but also in comparing the embryos of different species or related genera of conifers.

The embryos of the seeds of all sizes coming from six of the trees concerned in the first part of this paper were dissected out. These were classified as to their stage of development and measured under low magnification with an ocular micrometer. Two measurements were taken: diameter (d) of the embryonic cylinder near the widest part of its upper end (near the plerome apex in smaller embryos; across the cotyledons in the later stages); length (l) from the stem tip or tip of the cotyledons, whichever is the longer, to the place where the suspensor begins. The suspensor consists of elongated cells while the adjacent root cap has small cells more nearly isodiametric.

There were very many embryos that belonged to the same size of seed and to the same stage of development, of which the mean diameter and the mean length only was entered in the tables. The number of embryos belonging to each of these classes is indicated in the column showing frequency (f). Measurements were all converted to microns and may be considered accurate only to about 8 micron units where the frequency is only one.

It was believed that the ratio of diameter to length (d/l) would be useful in these comparisons. These are shown in all of the tables and are interesting insofar as they reveal general tendencies in all of the embryos of certain trees to be more slender or more stout at any and all stages of development. The d/l ratio is relatively high for the earlier stages and diminishes rapidly in early stages, more gradually as the embryos approach the condition of ripe seeds. Aside from the fact that differences in the d/l ratio exist in the embryos of different trees, no other particular significance may be attached to this item at the present time.

The embryos of stages in which the cotyledons have begun to form included counts of the cotyledons primordia or cotyledons. A few of the earliest sets of measurements did not include counts of the cotyledons; hence the frequency of the cotyledon counts is below the frequency of the set of measurements of embryos in two of the trees. In all cases the cotyledon counts were extensive enough to provide a satisfactory random sample, and are complete for the embryos of most of the trees.

Before this investigation was undertaken, it had been assumed, speculatively that an embryo might be expected to differentiate its stem tip and cotyledons when the embryonic cell mass reached a certain size or volume. This idea would suppose that conditions within the embryo determine the point at which differentiation would begin.

The results of these tabulations have shown that this idea was erroneous. They show clearly that even in these earliest stages of differentiation the embryo is very definitely influenced by the size of the seed.

It is remarkable to find that the increase in size of the embryos follows the increase in the size of the seeds so closely. There are some variations and irregularities as may be expected in all limited samples of biological material. The greatest digressions appear where individual embryos or small numbers of them are averaged as indicated by the frequency (f) for the class.

There can be no doubt that the size of the female gametophyte enters into the size relationship of the embryo at the time of differentiation. The female gametophyte is formed long before the embryo and surrounds the latter at all times, serving as endosperm in the matured seed. However efforts to measure and evaluate the endosperm have failed thus far. No satisfactory method has been divised by which the differences and irregularities found may be shown. The difficulty is primarily one of measurement and a lack of knowledge of the precise history of this member in its growth and maturity within the seed, throughout the period of development. We must content ourselves with the knowledge that the gametophyte or endosperm must also be limited by the size of the seed; realizing that seed size must serve as the nearest indirect measure of the endosperm.

When the embryos of stages III-VI are compared in the largest vs. smallest seeds, the volumes of the embryos are probably the important measure of differences. A few comparisons have been made by calculating the relative volumes of the embryos, which are from 2-4 times as large in the largest seeds as in the smallest. Estimates could be made of the relative volumes of the corresponding seeds, but their volumes appear to be from 3-5 times as large in the large seeds as in the small ones. There is enough agreement between these values to indicate that a very high correlation may be expected, but not a perfect one, between the volumes of the embryos dissected from large vs. small seeds and the volumes of the seeds themselves. The entire series of data on the sizes of embryos in relation to seed size point to the conclusion that the size of the partially developed embryo during which its organs become differentiated is conditioned by the size of the seed. The larger the seed, the larger the embryo becomes before its stem tip and cotyledons appear.

The question of the cause of variation in the number of cotyledons in pine embryos has always been one of interest to morphologists. A recent survey by Butts and Buchholz (7) shows how these are known to vary throughout conifers. At one time the senior author (4) was concerned with this problem in the Jack Pine, the Black Spruce in Larix, Cedrus and a few other conifers. The conclusions reached, following the more formal morphology, indicated that in the ontogeny of some embryos, the cotyledon number is reduced through fusion of small cotyledonary primordia and sometimes through the abortion of some of

these primordia. This was considered a sort of recapitulation in the embryogeny which was interpreted as indicating that phylogenetically the number of cotyledons was reduced from the large number shown in some pines to the smaller number shown in others.

Many of these embryos showed similar evidence of fusion of cotyledons in stages V and VI. However, when it became apparent that another factor, seed size, has a much more profound influence on the size of the embryo at the time when the cotyledonary primordia first appear, this phase of the investigation was not pursued further. At best the observed evidence of fusions could not account for a reduction in the number of cotyledons by as much as one seed leaf per embryo, while the differences due to seed size bring about differences in the number of cotyledons of about five per embryo. In any repetition of this type of investigation, one would need to take into account the size of the embryo and seed.

The largest number of cotyledons observed in any embryos was 14, the smallest 6. The mean of the largest embryos in the largest seeds was 12.2, and in the smallest embryos found in the smallest seeds it was 7.3 —a difference of 5 cotyledons.

The number of cotyledons is definitely related to the sizes of the seeds, as shown in the tabulations of the embryos dissected from the 6 trees studied. This condition is shown throughout the series. The mean number of cotyledons per embryo found in seeds of the same size in different trees is not precisely the same, but on any one tree the results are consistent when they are based on the means of more than a few embryos.

The results actually show that the embryos which are the smallest at the time of differentiation have the smallest number of cotyledons, and these are found in the smallest seeds. The largest embryos have the largest number of cotyledons, and are found in the largest seeds. There is a variability throughout that is a well known characteristic of cotyledon numbers.

A small embryo at the time of differentiation of these organs would have a smaller circumference on the shoulder of the embryo surrounding the stem tip, so that a smaller number of primordia could be formed. It is only in the largest seeds that the circle of this cotyledonary shoulder is large enough to accommodate the 5 or more additional primordia found in these.

It follows from this that the stem tip primordium must be largest in the embryos which happen to develop within large seeds. This larger stem primordium would have more volume and be composed of a larger number of cells, when surrounded by a larger number of cotyledons. No doubt the more rapid initial growth in the seedlings coming from large seeds is due to a larger, more robust embryo as well as to a larger reserve food supply in the endosperm. That this difference is only of temporary advantage was shown by the work of Righter (12) in his comparison of the seedlings of hybrid origin with the seedlings originating from the wind pollination with both classes coming from seeds of equal weight.

A practical question which would occur to foresters is whether or not any of the seeds collected for this series of observations would actually germinate. No experiments were carried out that would answer this question, which would probably depend upon the condition of the endosperm as well as the stage of the embryo. However our tabulations

of embryo maturity on certain dates may be compared with those of Maki (10), who made a series of records of seed germination in cones that were harvested prematurely in Idaho. None of the cones harvested in July contained seeds that would germinate. The cones from which he extracted seeds that would germinate were collected on August 6. These gave about 5 percent germination. His seeds of August 16, gave about 50 percent germination while his later collections were somewhat better. There is good reason to suppose that seeds with embryos in stage VIII might grow, possibly some of those in stage VII. Our table showing the embryos of tree 3-40, collected August 5, which had 158 embryos in stage VIII might be expected to give 36 percent germination, but tree 3-52 collected on the same day, with only 3 embryos in this stage might be expected to show only about 1 percent germination, about 11 percent if stage VII is included in the count of viable seeds.

Our work shows therefore that among different trees growing on a given site there are differences in the degree of maturity of the embryos, when cones are harvested prematurely. Of course the altitude of the site would affect this, and in a comparison of seeds in Idaho and California would involve an allowance for latitude.

TABLE 2.—EMBRYOS DISSECTED FROM SEEDS OF VARIOUS SIZES OF PINUS PONDEROSA

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TABLE 2.—EMBRYOS DISSECTED FROM SEEDS OF VARIOUS SIZES OF PINUS PONDEROSA
Tree 3-14, collected Aug. 1, 5, 1942. Elevation 3700 ft.

Seed sizes	Stage II				Stage III				Stage IV					Stage V				
	f	d	l	d/l	f	d	l	d/l	f	d	l	d/l	Cots.	f	d	l	d/l	Cots.
12	0	....	....	....	0	....	....	....	1	630	1303	.48	8	0	....	....	....	.....
13	2	422	716	.59	0	....	....	....	4	564	1401	.40	9	0	....	....	....	.....
14	6	413	727	.57	4	531	977	.54	8	662	1313	.50	9.8	7	793	1726	.46	9.7
15	5	489	879	.56	7	576	1259	.46	17	695	1497	.46	10.5	13	858	1867	.46	9.9
16	5	564	771	.74	9	727	1205	.60	6	737	1564	.47	10.4	10	847	1965	.43	10.5
17	4	499	902	.55	4	662	1541	.43	4	766	1466	.52	11.0	4	890	1998	.45	10.9
18	0	....	....	....	0	....	....	....	0	....	....	....	.....	3	1031	1993	.52	11.3
Total	22	476	802	.59	24	640	1233	.52	40	687	1453	.47		37	860	1892	.45	

Seed sizes	Stage VI					Stage VII					Stage VIIIa					Cotyledons	
	f	d	l	d/l	Cots.	f	d	l	d/l	Cots.	f	d	l	d/l	Cots.	f	Summary by seed sizes
12	1	727	2117	.34	9	0	....	....	....	.....	0	....	....	....	.....	2	8.50
13	2	814	1849	.44	10	1	956	2605	.37	12	0	....	....	....	.....	7	9.57
14	15	879	2476	.36	10.3	3	1042	2952	.35	11.7	2	1096	3018	.36	12	32	10.37
15	13	956	2150	.44	10.1	8	1107	3050	.36	11.1	5	1215	3865	.31	10.8	43	10.42
16	7	998	2410	.41	10.9	11	1150	3061	.37	11.3	8	1292	4082	.32	10.1	37	10.67
17	5	1064	2649	.40	12.0	4	1227	3387	.36	11.8	3	1336	3778	.35	12.3	20	11.50
18	1	1248	2660	.47	13.0	1	1411	3582	.39	14.0	0	....	....	....	.....	5	12.20
Total	44	944	2356	.42		28	1140	3095	.37		18	1257	3853	.33			

In this and the following tables the symbols are: f=frequency, d=diameter of embryo; l=length of embryonic cylinder, exclusive of suspensor; d/l=ratio of diameter divided by lengths; Cots.=cotyledons. For seed sizes and stages of embryos see text and Fig. 1. Measurements are given in microns, by conversion from larger units.

TABLE 2.—EMBRYOS DISSECTED FROM SEEDS OF VARIOUS SIZES OF PINUS PONDEROSA—Continued

Tree 3-57, collected Aug. 1, 2, 1942. Elevation 3700 ft.

Seed sizes	Stage II				Stage III				Stage IV					Stage V				
	f	d	l	d/l	f	d	l	d/l	f	d	l	d/l	Cots.	f	d	l	d/l	Cots.
12	0	....	....	....	0	....	....	....	0	....	....	....	.....	2	739	2313	.32	9.5
13	2	261	434	.60	1	662	1737	.38	10	651	1726	.38	.....	18	727	1933	.38	10.2
14	1	359	706	.51	0	....	....	....	3	673	1802	.37	.....	6	859	2301	.37	11.0
Total	3	294	524	.56	1	662	1737	.38	13	658	1745	.38		26	753	2047	.37	

Seed sizes	Stage VI					Stage VII					Stage VIIIa					Cotyledons	
	f	d	l	d/l	Cots.	f	d	l	d/l	Cots.	f	d	l	d/l	Cots.	f	Summary by seed sizes
12	0	....	....	....	.....	8	923	2788	.33	8.8	0	....	....	....	.....	10	9.00
13	18	825	2336	.35	9.3	33	902	2768	.32	9.6	11	1042	3463	.30	9.7	25	9.72
14	7	847	2388	.35	10.8	10	933	2692	.35	10.2	5	1086	3376	.32	11.5	19	10.89
Total	25	832	2346	.35		51	910	2738	.33		16	1054	3436	.31			

Tree 15-43, collected Aug. 14, 1942. Elevation 4100 ft.

Seed sizes	Stage II				Stage III				Stage IV					Stage V				
	f	d	l	d/l	f	d	l	d/l	f	d	l	d/l	Cots.	f	d	l	d/l	Cots.
10	1	207	260	.79	5	406	701	.58	4	472	1067	.45	7	3	568	1375	.41	6.3
11	0	....	....	....	0	....	....	....	1	520	1324	.39	8	5	641	1499	.43	7.6
12	2	266	363	.73	2	445	933	.48	5	602	1182	.51	9	7	674	1607	.42	8.6
13	3	307	505	.61	1	489	977	.50	6	641	1278	.50	9	20	730	1604	.46	9.4
14	1	413	597	.69	0	....	....	....	3	604	1287	.47	10	4	765	1639	.47	9.1
15	0	....	....	....	0	....	....	....	0	....	....	....	.....	1	781	1704	.46	10.0
Total	7	296	445	.66	8	426	794	.54	19	583	1234	.47		40	702	1580	.44	

Seed sizes	Stage VI					Stage VII					Stage VIIIa					Cotyledons	
	f	d	l	d/l	Cots.	f	d	l	d/l	Cots.	f	d	l	d/l	Cots.	f	Summary by seed sizes
10	1	706	2171	.33	7	0	....	....	....	.....	0	....	....	....	.....	8	6.77
11	6	741	1788	.41	7.7	0	....	....	....	.....	0	....	....	....	.....	12	7.83
12	7	807	2112	.38	8.6	6	903	2551	.35	9.2	0	....	....	....	.....	25	8.40
13	18	833	2142	.39	9.3	28	946	2904	.33	9.1	6	1126	3827	.29	9.2	79	9.23
14	13	868	2138	.41	9.2	29	998	2904	.34	9.4	7	1143	3810	.30	9.6	55	9.34
15	3	958	2204	.43	9.3	8	1066	2877	.37	10.1	2	1080	3772	.29	10.0	14	9.94
Total	48	884	2072	.43		71	977	2862	.34		15	1128	3811	.30			

TABLE 2.—EMBRYOS DISSECTED FROM SEEDS OF VARIOUS SIZES OF PINUS PONDEROSA—Continued

Tree 3-56, collected Aug. 5, 8, 12, 1942. Elevation 3700 ft.

Seed sizes	Stage II				Stage III				Stage IV					Stage V				
	f	d	l	d/l	f	d	l	d/l	f	d	l	d/l	Cots.	f	d	l	d/l	Cots.
10	0	...	...	...	0	...	...	...	...	...	...	...	...	3	608	1646	.37	7.6
11	1	217	282	.77	1	326	597	.55	5	439	1051	.42	7.8	13	630	1624	.39	8.5
12	2	299	461	.65	1	510	1140	.45	4	608	1520	.40	9.3	6	701	1677	.40	9.3
13	0	...	...	...	0	...	...	...	0	...	...	...	...	2	743	1764	.42	9.5
Total	3	271	401	.68	2	418	868	.48	9	514	1259	.41		24	655	1652	.40	

Seed sizes	Stage VI					Stage VII					Stage VIII					Cotyledons	
	f	d	l	d/l	Cots.	f	d	l	d/l	Cots.	f	d	l	d/l	Cots.	f	Summary by seed sizes
10	2	614	1529	.40	8	...	...	...	...	...	...	...	...	...	...	5	7.80
11	24	629	1765	.36	7.9	35	748	2539	.29	8.7	15	886	3461	.26	9.1	92	8.49
12	10	800	2189	.37	9.1	39	906	2899	.31	9.3	82	1127	3968	.28	10.	140	9.7
13	2	868	2334	.37	10.5	10	896	3066	.29	8.9	48	1279	4424	.29	10.3	62	10.06
Total	38	671	1894	.35		84	839	2771	.30		145	1152	4066	.28			

Tree 3-40, collected Aug. 5, 1942. Elevation 3700 ft.

Seed sizes	Stage II				Stage III				Stage IV					Stage V				
	f	d	l	d/l	f	d	l	d/l	f	d	l	d/l	Cots.	f	d	l	d/l	Cots.
12	2	389	608	.64	....	....	....	....	....	....	....	....	.....	1	608	1628	.37	8.0
13	....	....	....	....	....	....	....	....	....	....	....	....	.....	2	608	1378	.44	8.0
14	....	....	....	....	....	....	....	....	....	....	....	....	.....	1	825	1716	.48	10.0
15	3	513	1005	.51	....	....	....	....	3	781	1324	.59	11	2	825	1683	.49	9.0
16	1	455	673	.68	....	....	....	....	....	....	....	....	.....	2	868	2008	.43	10.5
Total	6	466	818	.57	....	....	....	....	3	781	1324	.59		8	754	1686	.45	

Seed sizes	Stage VI					Stage VII					Stage VIII					Cotyledons	
	f	d	l	d/l	Cots.	f	d	l	d/l	Cots.	f	d	l	d/l	Cots.	f	Summary by seed sizes
12	....	....	....	....	.....	....	....	....	....	.....	4	1146	3705	.31	7.5	5	7.80
13	1	825	1716	.48	10	13	1005	3148	.32	9.2	29	1299	4742	.27	9.5	45	9.82
14	....	....	....	....	.....	24	1075	3105	.35	10.3	54	1278	4630	.28	9.9	79	10.04
15	4	912	2177	.42	10	9	1054	3158	.33	10.0	55	1310	4589	.29	10.2	73	10.14
16	....	....	....	....	.....	11	1042	3311	.31	10.5	16	1371	4961	.28	10.1	29	10.31
Total	5	894	2084	.43		57	1045	3214	.33		158	1299	4646	.28			

TABLE 2.—EMBRYOS DISSECTED FROM SEEDS OF VARIOUS SIZES OF PINUS PONDEROSA—Concluded

Tree 3-52, collected Aug. 5, 1942. Elevation 3700 ft.

Seed sizes	Stage II				Stage III				Stage IV					Stage V				
	f	d	l	d/l	f	d	l	d/l	f	d	l	d/l	Cots.	f	d	l	d/l	Cots.
11	0	....	....	....	1	413	651	.63	1	564	1107	.51	9	1	608	1086	.56	9
12	0	....	....	....	2	434	802	.54	1	586	1151	.51	8	4	628	1309	.48	9
13	0	....	....	....	0	....	....	....	0	....	....	....	.....	2	630	1476	.43	10
14	0	....	....	....	0	....	....	....	0	....	....	....	.....	0	....	....	....	.....
Total	....	....	....	....	3	427	753	.57	2	576	1129	.51		7	625	1324	.47	

Seed sizes	Stage VI					Stage VII					Stage VIII					Cotyledons	
	f	d	l	d/l	Cots.	f	d	l	d/l	Cots.	f	d	l	d/l	Cots.	f	Summary by seed sizes
11	1	737	2084	.35	9	1	868	2410	.36	9	....	....	....	....	.....	4	9.
12	6	779	2008	.39	9	8	896	2685	.33	9.25	1	977	3626	.27	9	20	9.10
13	19	797	2150	.37	9.3	18	886	2859	.31	9.06	2	1096	3691	.30	10.5	41	9.2
14	0	....	....	....	.....	1	956	2779	.34	8.0	0	....	....	....	.....	1	8.00
Total	26	791	2117	.37		28	890	2791	.32		3	1056	3671	.29			

A CHECK LIST OF THE VASCULAR PLANTS OF *JO DAVIESS COUNTY, ILLINOIS*

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Jo Daviess County is situated at the northwestern corner of the State of Illinois in an angle formed by the boundary of the State of Wisconsin and the Mississippi River, and is unique in possessing the highest elevations in the state. Its irregular topography proves that the greater part of the county shows no evidence of glaciation but some moranic deposits are found along a narrow strip of its eastern boundary. Isolated hills, capped by Niagara limestone over Maquoketa shale, are scattered through the county, the most notable being Charles Mound and Benton Mound rising to heights of 1246 and 1226 feet respectively. The bluffs of the Mississippi River are more than 150 feet high while the secondary streams, flowing in a general southwesterly direction, have cut their channels deeply into the underlying limestone forming cliffs and canyons of considerable size. Those of the Galena and Apple Rivers are most notable.

These topographic features have provided a great variety of habitats for a particularly rich and varied flora. Among these habitats the following are noteworthy: the terraces of the Mississippi with its sand ridges, its sand prairies, and its alluvial flood plains; the river bluffs and limestone cliffs; the Apple River Canyon with its dripping banks; the rolling hillsides with its upland forests; the non-glaciated plains with its high prairies (now occupied by pastures and cornfields); the glaciated plains with its low prairies and swamps; the mounds with their dry hill tops; and the right of way of the railroads with its ruderals and its introduced plants all provide space for a flora of well above 1200 species.

The late Dr. H. S. Pepoon, whose boyhood was spent in this county, made the vegetation of the area familiar to the people of the state in several publications (1). He was largely instrumental in getting a portion of the picturesque valley of the Apple River set aside as the Apple River State Park. He made many collecting trips through all parts of the county, during both his earlier and his later years. Unfortunately, his herbarium was destroyed by fire, but he kept detailed notes of his trips and his notebooks have been preserved. These have been made available through the courtesy of his daughter, Mrs. M. W. Buckley, and have been used in compiling this check list. Pepoon's compilation seems to have been made about 1920 and apparently contains all his collections including the earliest. Doubtless some of the rare original species, not noted in recent years, have disappeared with the clearing of the forests and with the cultivation of the prairies.

The species in this list have been checked against specimens in the herbarium of the University of Illinois at Urbana collected by Pepoon, Umbach, Moffatt, Jones and others, and against those collected by the

writer in the herbarium of the Illinois State Museum at Springfield. All in the Pepoon list have been found in these herbaria with the exception of those followed by an asterisk (*).

The order of the families and genera and the nomenclature, with a very few exceptions, are those of the recently published *Flora of Illinois* by G. N. Jones (2).

Ophioglossaceae

Botrychium obliquum Muhl.
Botrychium virginianum (L) Sw.

Osmundaceae

Osmunda claytoniana L.

Polypodiaceae

Woodsia obtusa (Spreng.) Torr.
Cystopteris bulbifera (L.) Bernh.
Cystopteris fragilis (L.) Bernh.
Pteretis nodulosa (Michx.) Nieuwl.
Onoclea sensibilis L.
Dryopteris hexagonoptera (Michx.) C. Ch.
Dryopteris noveboracensis (L.) Gray
Dryopteris thelypteris var. pubescens (Lawson) Prince
Dryopteris marginalis (L.) Gray
Dryopteris spinulosa (Muell.) Watt.
Polystichum acostichoides (Michx.) Schott.
Athyrium angustum (Willd.) Presl.
Athyrium pycnocarpon (Spreng.) Tidestr.
Athyrium thelypteroides (Michx.) Desv.
Camptosorus rhizophyllus (L.) Link
Pellaea glabella Mett.
Cheilanthes feei Moore
Pteridium aquilinum (L.) Kuhn.
Cryptogramma stelleri (Gmel.) Prantl.
Adiantum pedatum L.

Equisetaceae

Equisetum arvense L.
Equisetum fluvitile L.*
Equisetum laevigatum A. Br.
Equisetum prealtum Raf.
Equisetum scirpoides Michx.*
Equisetum variegatum Schleich.

Lycopodiaceae

Selaginella apoda (L.) Fern.*
Selaginella rupestris (L.) Spreng.

Isoetaceae

Isoetes melanopoda J. Gay.*

Taxaceae

Taxus canadensis Marsh.

Pinaceae

Pinus strobus L.
Juniperus communis L. var. depressa Pursh
Juniperus virginiana L.

Typhaceae

Typha latifolia L.

Sparganiaceae

Sparganium americanum Nutt.
Sparganium androcladum (Engelm.) Morong.
Sparganium eurycarpum Engelm.

Potamogetonaceae

Potamogeton americanus C. & S.
Potamogeton amplifolius Tuck.
Potamogeton foliosus Raf.*
Potamogeton friesii Rupr.*
Potamogeton lucens L.
Potamogeton natans L.
Potamogeton pectinatus L.
Potamogeton praelongus Wulf.*
Potamogeton pusillus L. *
Potamogeton zosteriformis Fern.

Najadaceae

Najas flexilis (Willd.) R. & S.*

Alismaceae

Alisma subcordatum Raf.
Lophotocarpus calycinus (Engelm.) Sm.*
Sagittaria latifolia Willd.
Sagittaria rigida Pursh*

Hydrocharitaceae

Anacharis canadensis (Michx.) Planch.

Gramineae

Bromus ciliatus L.
Bromus commutatus Schrad.
Bromus inermis Leyss
Bromus kalmii Gray
Bromus purgans L.
Bromus racemosus Schrad.*
Bromus secalinus L.*
Bromus tectorum L.
Festuca elatior L.*
Festuca obtusa Spreng.
Festuca octoflora Walt.
Festuca ovina L.*
Glyceria borealis (Nash.) Batch.*
Glyceria grandis Wats.
Glyceria septentrionalis Hitchc.
Glyceria striata (Lam.) Hitchc.
Poa annua L.
Poa chapmaniana Scribn.*
Poa compressa L.
Poa debilis Torr.*

Poa palustris L.
Poa pratensis L.
Poa sylvestris Gray
Eragrostis capillaris (L.) Nees.
Eragrostis cilianensis (All.) Link
Eragrostis frankii Meyer
Eragrostis hypnoides (Lam.) BSP.
Eragrostis pectinacea (Michx.) Nees.
Eragrostis pilosa (L.) Beauv.*
Eragrostis spectabilis (Pursh) Steud.
Diarrhena americana Beauv.
Dactylis glomerata L.
Phragmites communis Trin.
Melica mutica Walt.
Triodia flava (L.) Smyth
Triplasis purpurea (Walt.) Chapm.*
Agropyron caninum (L.) Beauv.*
Agropyron pauciflorum (Schw.) Hitchc.*
Agropyron repens (L.) Beauv.
Agropyron smithii Rydb.
Elymus canadensis L.
Elymus villosus Muhl.
Elymus virginicus L.
Hystrix patula Moench.
Hordeum jubatum L.
Koeleria cristata (L.) Pers.
Sphenopholis intermedia Rydb.
Sphenopholis obtusata (Michx.) Scribn.
Deschampsia caespitosa (L.) Beauv.
Avena fatua L.*
Danthonia spicata (L.) Beauv.
Calamagrostis canadensis (Michx.) Beauv.
Calamagrostis inexpansa Gray
Calamovilfa longifflolia (Hook.) Scribn.
Agrostis alba L.
Agrostis hiemalis (Walt.) BSP.
Agrostis perennans (Walt.) Tuck.
Cinna arundinacea L.
Cinna latifolia (Trev.) Griseb.*
Alopecurus aequdlis Sobol.*
Alopecurus geniculatus L.
Phleum pratense L.
Muhlenbergia foliosa (R. & S.) Trin.
Muhlenbergia mexicana (L.) Trin.
Muhlenbergia schreberi Gmel.
Muhlenbergia sylvatica Torr.
Muhlenbergia teniuflora (Willd.) BSP.
Sporobolus clandestinus (Spreng.) Hitchc.*
Sporobolus cryptandrus (Torr.) Gray
Sporobolus heterolepsis Gray
Sporobolus neglectus Nash.
Sporobolus vaginflorus (Torr.) Wood*
Brachyelytrum erectum (Schreb.) Beauv.
Oryzopsis asperifolia Michx.
Oryzopsis asperifolia Michx.
Oryzopsis racemosa (Sm.) Ricker
Stipa spartea Trin.
Aristida basiramea Engelm.*
Aristida dichotoma Michx.
Aristida oligantha Michx.
Aristida purpurascens Poir.
Aristida ramosissima Engelm.*
Aristida tuberculosa Nutt.
Eleusine indica Gaertn.
Spartina pectinata Link
Bouteloue curtipendula (Michx.) Torr.
Bouteloua gracilis (HBK.) Torr.
Bouteloua hirsuta Lag.
Hierochloe odorata (L.) Beauv.*
Phalaris arundinaces L.
Phalaris canariensis L.*
Leersia lenticularis Michx.
Leersia oryzoides (L.) Sw.
Leersia virginica Willd.*
Digitaria ischaemum (Schreb.) Muhl.
Digitaria sanguinalis (L.) Scop
Leptoloma cognatum (Schult.) Chase
Paspalum stramineum Nash.
Panicum agrostoides L.*
Panicum boscii Poir.
Panicum capillare L.
Panicum clandestinum L.
Panicum depauperatum Muhl.*
Panicum dichotomum L.
Panicum dichotomiflorum Michx.
Panicum huachucae Ashe
Panicum implicatum Schribn.*
Panicum latifolium L.
Panicum leibergii (Vasey) Schribn.
Panicum miliaceum L.
Panicum perlongum L.*
Panicum pseudopubescens Nash.
Panicum scribnerianum Nash.
Panicum tennesseense Ashe*
Panicum verrucosum Muhl.*
Panicum villossimum Nash.
Panicum virgatum L.
Panicum wilcoxianum Vasey*
Echinochloa crus-galli (L.) Beauv.
Echinochloa walter (Pursh) Heller*
Setaria italica L.*
Setaria lutescens (Weigel) Hubb
Setaria verticillata (L.) Beauv.*
Setaria viridis (L.) Beauv.
Cenchrus longspinus (Hack.) Fern.
Andropogon furcatus Muhl.
Andropogon scoparius Michx.
Sorghastrum nutans (L.) Nash.

Cyperaceae

Cyperus aristatus Roth
Cyperus diandrus L.
Cyperus esculentus L.*
Cyperus engelmannii Steud.
Cyperus erythrorhizos Muhl.*
Cyperus ferruginescens Boeckl.*
Cyperus filiculmis Vehl.
Cyperus rivularis Kunth.
Cyperus schweinitzii Torr.
Cyperus strigosus L.
Dulichium arundinaceum (L.) Britt.
Eleocharis acicularis (L.) R. & S.*
Eleocharis engelmannii Steud.*

Eleocharis equisetoides (Ell.) Torr.*
Eleocharis internedia (Muhl.) Schult.*
Eleocharis obtusa (Willd.) Schult.
Eleocharis ovata (Roth.) R. & S.
Eleocharis palustris (L.) R. & S.
Eleocharis qudrangulata (Michx.) R. & S.
Eleocharis tenuis (Willd.) Schult.
Bulbostylis capillaris (L.) Clarke
Hemicarpa micrantha (Vahl.) Britt.
Fimbristylis autumnalis (L.) R. & S.
Scirpus americanus Pers.
Scirpus atrovirens Muhl.
Scirpus cyperinus (L.) Knuth.
Scirpus debilis Pursh*
Scirpus fluviatilis (Torr.) Gray*
Scirpus lineatus Michx.
Scirpus polyphyllus Vahl.
Scirpus validus Vahl.
Eriophorum angustifolium Roth.*
Rhynchospora alba (L.) Vahl.*
Carex aggregata Mack.
Carex albursina Boott.
Carex aquatilis Wahl.*
Carex artitecta Mack.
Carex aurea Nutt.
Carex bicknellii Britt.*
Carex blanda Dewey
Carex brunnescens Poir.
Carex cephaloidea Dewev
Carex cephalophora Muhl.*
Carex communis Bailey*
Carex comosa Boott.
Carex crinita Lam.*
Carex cristatella Britt.*
Carex davisii Schw.
Carex debilis Michx.
Carex disperma Dewey*
Carex eburnea Boott.
Carex festucacea Schk.
Carex filiformis L.
Carex foenae Willd.
Carex gracillima Schw.
Carex granularis Muhl.*
Carex gravida Bailey
Carex grisea Wahl.
Carex grayii Carey
Carex hirtifolia Mack.*
Carex hystricina Muhl.
Carex interior Bailey*
Carex intumescens Rudge
Carex jamesii Schw.*
Carex lanuginosa Michx.
Carex laxiflora Lam.
Carex laptalea Wahl.*
Carex longirostris Torr.
Carex lupulina Muhl.
Carex lurida Wahl.
Carex meadii Bailey*
Carex muskingumensis Schw.
Carex muhlenbergii Schw.
Carex oligocarpa Scht.
Carex pedunculata Muhl.
Carex pennsylvanica L.
Carex plantaginea Lam.
Carex prairea Dewey*
Carex pubescens Muhl.
Carex retrorsa Schw.
Carex rosea Schk.
Carex sartwellii Dewey*
Carex scoparia Schk.
Carex springelli Dewey*
Carex stipata Muhl.
Carex straminea Willd.
Carex stricta Lam.
Carex suberecta (Olney) Britt.*
Carex tenera Dewey
Carex tetanica Schk.*
Carex torta Boott.*
Carex tribuloides Wahl.
Carex tuckermannii Dewey*
Carex varia Muhl.
Carex virescens Muhl.
Carex vulpinoidea Michx.

Araceae

Arisaema atrorubens (Ait.) Blume
Arisaema dracontium (L.) Schott.
Symplocarpus foetidus (L.) Nutt.
Acorus calamus L.

Lemnaceae

Lemna minor L.
Lemna perpusilla Torr.*
Lemna trisulca L.
Spirodela polyrhiza (L.) Schleid.
Wolffia columbiana Karst.

Commelinaceae

Commelina communis L.
Commelina virginica L.
Tradescantia canaliculata Raf.
Tradescantia virginiana L.

Pontederiaceae

Pontederia cordata L.
Heteranthera dubia (Jacq.) MacD.
Juncus acuminatus Michx.
Juncus balticus var. littoralis Engelm.
Juncus buffonius L.*
Juncus canadensis J. Gay
Juncus interior Wieg.*
Juncus macer S. F. Gray
Juncus nodosus L.
Juncus secundus Beauv.*
Juncus vasey Engelm.*
Luzula multiflora (Ehrh.) Lej.

Liliaceae

Zigadenus glaucus Nutt.
Hemorocallis fulva L.
Allium canadense L.
Allium cernuum Roth.
Allium stellatum Ker.
Allium tricoccum Ait.
Lilium michiganense Farw.
Lilium umbellatum Pursh
Erythronium albidum Nutt.

Erythronium americanum Ker.*
Camassia scillioides (Raf.) Cory
Asperagus officinalis L.
Smilacina racemosa (L.) Desf.
Smilacina stellata (L.) Desf.
Maianthemum canadense var. interius Fern.
Polygonatum biflorum (Walt.) Ell.
Polygonatum pubescens (Willd.) Pursh
Uvularia grandiflora Sm.
Uvularia sessilifolia L.*
Trillium gleasoni Fern.
Trillium recurvatum Beck.
Trillium sessile L.*
Smilax ecirrhata (Engelm.) Wats.
Smilax herbacea L.
Smilax hispida Muhl.
Smilax rotunidifolia L.

Dioscoreaceae

Dioscorea villosa L.

Amaryllidaceae

Hypoxis hirsuta (L.) Coville

Iridaceae

Iris shrevei Small
Sisyrinchium albidum Raf.
Sisyrnchium angustifolium Mill.
Sisyrinchium graminoides Bickn.

Orchidaceae

Cypripedium candidum Muhl.*
Cypripedium hirsutum Mill.
Cypripedium reginea Walt.
Orchis spectabilis L.
Habenaria bracteata (Muhl.) R. Br.
Habenaria clavellata (Michx.) Spreng.
Habenaria flava (L.) Gray*
Habenaria lacera (Michx.) R. Br.
Habenaria leucophaea (Nutt.) Gray*
Calopogon pulchellus (Salisb.) R. Br.
Triphora trianthophora (Sw.) Rydb.
Spiranthes gracilis (Bigel.) Beck.*
Goodyera pubescens (Willd.) R. Br.*
Liparis liliifolia (L.) Rich.
Liparis loeselii (L.) Rich.*
Aplectrum hyemale (Muhl.) Torr.
Corallorrhiza maculatum Raf.

Saururaceae

Saururus cernuus L.

Salicaceae

Populus alba L.
Populus deltoides Marsh.
Populus grandidentata Michx.
Populus tremuloides Michx.
Salix amygaloides Anders.
Salix bebbiana Sarg.
Salix candida Fluegge.
Salix cordata Muhl.
Salix discolor Muhl.
Salix fragilis L.*
Salix glaucophylla Bebb.
Salix humilis Marsh.
Salix interior Rowlee
Salix lucida Muhl.
Salix nigra Marsh.
Salix pedicellaris Pursh.*
Salix petiolaris Sm.
Salix sericea Marsh.

Juglandaceae

Juglans cinerea L.
Juglans nigra L.
Carya cordiformis (Wang.) K. Koch.
Carya glabra (Mill.) Sweet
Carya illinoensis (Wang.) K. Koch.*
Carya laciniosa (Michx. f.) Loud.
Carya ovata (Mill.) K. Koch.

Betulaceae

Corylus americana Walt.
Ostrya virginiana (Mill.) Koch.
Carpinus caroliniana Walt.
Betula lutea Michx. f.
Betula nigra L.
Betula papyrifera Marsh.

Fagaceae

Quercus alba L.
Quercus bicolor Willd.
Quercus borealis Michx. f.
Quercus ellipsoidalis Hill.
Quercus macrocarpa Michx.
Quercus muhlenbergia Engelm.
Quercus palustris Muench.*
Quercus velutina Lam.

Ulmaceae

Ulums americana L.
Ulmus fulva Michx.
Ulmus thomasi Sarg.
Celtis occidentalis L.
Morus rubra L.

Cannabinaceae

Cannabis sativa L.
Humulus americanus Nutt.

Urticaceae

Urtica dioica L.*
Urtica procera Muhl.
Boehmera cylindrica (L.) Sw.
Pilea pumila (L.) Gray
Laportea canadensis (L.) Gaud.
Parietaria pennsylvanica Muhl.

Santalaceae

Comandra umbellata (L.) Nutt.

Aristolochiaceae

Asarum acuminatum (Ashe) Bickn.
Asarum reflexum Bickn.

Polygonaceae

Rumex acetosella L.
Rumex altissimus Wood
Rumex britannica L.
Rumex crispus L.
Rumex obtusifolius L.
Rumex verticillatus L.
Polygonum aviculare L.
Polygonum dumetorum L.
Polygonum erectum L.*
Polygonum exsertum Small*
Polygonum hydropiper L.
Polygonum hydropiperoides Michx.
Polygonum lapathifolium L.
Polygonum orientale L.*
Polygonum pennsylvanicum L.
Polygonum persicaria L.
Polygonum punctatum Ell.
Polygonum scandens L.
Polygonum sagittatum L.
Polygonum tenue Michx.*
Polygonum virginianum L.
Polygonella articulata (L.) Meis.

Chenopodiaceae

Chenopodium album L.
Chenopodium ambrosioides L.*
Chenopodium botrys L.
Chenopodium capitatum L.
Chenopodium glaucum L.*
Chenopodium hybridum L.
Chenopodium pratericola Rydb.*
Chenopodium urbicum L.
Kochia scoparia (L.) Schrad.
Cycloloma atriplicifolium (Spreng.) Coult.
Atriplex hastata L.*
Atriplex patula L.
Coriospermum hyssopifolium L.
Salsola pestifer A. Nels.

Amaranthaceae

Amaranthus blitoides Wats.
Amaranthus gracaezans L.
Amaranthus hybridus L.
Amaranthus retroflexus L.
Amaranthus spinosus L.
Acnida altissima Riddell.
Acnida subnuda (Wats.) Stanley.*
Acnida tamariscina (Nutt.) Wood.*
Froelichia campestris Small.

Phytolaccaceae

Phytolacca americana L.

Nyctaginaceae

Oxybaphus linearis (Pursh) Rob.*
Oxybaphus nyctagineus (Michx.) Sweet

Illecebraceae

Paronychia canadensis (L.) Wood
Paronychia fastigiata (Raf.) Fern.*

Aizoaceae

Mollugo verticillata L.

Portulacaceae

Talinum rugospermum Holz.
Claytonia virginica L.
Portulaca oleracea L.

Caryophyllaceae

Cerastium nutans Raf.
Cerastium vulgatum L.
Stellaria aquatica (L.) Scop.
Stellaria longifolia Muhl.
Stellaria media (L.) Cyril.
Arenaria lateriflora L.
Arenaria serpyllifolia L.
Arenaria stricta Michx.
Agrostemma githago L.
Silene antirrhina L.
Sinene cucubalus Wibel.
Silene nivea (Nutt.) Otth.
Silene noctiflora L.
Silene stellata (L.) Ait.
Lychnis alba Mill.
Saponaria officinalis L.
Saponaria vaccaria L.*

Ranunculaceae

Caltha palustris L.
Hydrastis canadensis L.*
Isopyrum biternatum (Raf.) T. & G.
Aquilegia canadensis L.
Actaea alba (L.) Mill.
Actaea rubra (Ait.) Willd.
Ranunculus abortivus L.
Ranunculus acris L.*
Ranunculus fascicularis Muhl.
Ranunculus flabellaris Raf.*
Ranunculus hispidus Michx.
Ranunculus pennsylvanicus L. f.
Ranunculus recurvatus Poir.
Ranunculus repens L.
Ranunculus rhomboideus Goldie
Ranunculus sceleratus L.
Ranunculus septentrionalis Poir.
Ranunculus trichophyllus Chaix.
Thalictrum dasycarpum F. & L.
Thalictrum dioicum L.
Thalictrum revolutum DC.
Anemone candensis L.
Anemone caroliniana Walt.*
Anemone cylindrica Gray
Anemone ludoviciana Nutt.
Anemone quinquefolia L.
Anemone virginiana L.
Anemonella thalictroides (L.) Spach.
Hepatica acutiloba DC.
Clematis virginiana L.

Nymphaeaceae

Nelumbo lutea (Willd.) Pers.
Nuphar advena Ait.
Nymphaea tuberosa Paine

Ceratophyllaceae

Ceratophyllum demersum L.

Berberidaceae

Berberis vulgaris L.
Podophyllum peltatum L.
Jeffersonia diphylla (L.) Pers.
Caulophyllum thalictroides (L.) Meek.

Menispermaceae

Menispermum canadense L.

Lauraceae

Benzoin aestivale (L.) Nees.

Papaveraceae

Sanginaria canadensis L.

Fumariaceae

Dicentra canadensis (Goldie) Watts.*
Dicentra cucullaria (L.) Bernh.
Corydalis flavula (Raf.) DC.
Corydalis micrantha (Engelm.) Gray

Cruciferae

Brassica alba L.
Brassica arvensis (L.) Raben.
Brassica campestris L.
Brassica juncea (L.) Cosson.
Brassica nigra (L.) Koch.
Barbarea vulgaris R. Br.
Rorippa americana (Gray) Britt.
Rorippa palustris (L.) Bess.
Rorippa sessiflora (Nutt.) Hitchc.
Sisymbrium altissimum L.
Sisymbrium officinale (L.) Scop.
Conringia orientalis (L.) Dum.*
Erysimum cheiranthoides L.*
Descurainia brachycarpa (Rich.) Schulz.
Draba verna L.*
Dentaria laciniata Muhl.
Iodanthus pinnatafidus (Michx.) Steud.
Cardamine bulbosa (Schreb.) BSP.
Cardamine douglassii (Torr.) Britt.
Cardamine pennsylvanica Muhl.
Arabis canadensis L.
Arabis confinis Wats.
Arabis dentata T. & G.
Arabis hirsuta (L.) Scop.*
Arabis laevigata (Muhl.) Poir.
Arabis lyrata L.
Arabidopsis thaliana (L.) Heynh.*
Nasturtium officinale R. Br.
Armoracia aquatica (Eaton) Wieg.*
Armoracia rusticana Gaertn.
Camelina microcarpa Andrz.
Lepidium campestre (L.) R. Br.
Lepidium virginicum L.
Thlaspi arvense L.
Capsella bursa-pastoris (L.) Medic.

Capparidaceae

Polanisia graveolens Raf.
Polanisia trachysperma T. & G.
Cristatella jamesii T. & G.*

Crassulaceae

Penthorum sedoides L.

Saxifragaceae

Heuchera hispida Pursh
Mitella diphylla L.
Mitella nuda L.*
Chrysosplenium americanum Schw.*
Sullivantia renifolia Rosend.
Saxifraga forbesii Vasey
Saxifraga pennsylvanina L.
Saxifraga virginiana Michx.*
Parnassia glauca Raf.

Grossulariaceae

Ribes cynosbati L.
Ribes floridum L'Her.
Ribes missouriense Nutt.
Ribes oxycanthoides L.*

Hamamelidaceae

Hamamelis virginiana L.

Platanaceae

Platanus occidentalis L.

Rosaceae

Physocarpus opulifolius (L.) Maxim.
Spiraea alba DuRoi.
Aruncus dioicus (Walt.) Fern.
Fragaria americana (Perter) Britt.
Fragaria virginiana Duch.
Potentilla anserina L.*
Potentilla argentea L.
Potentilla arguta Pursh
Potentilla fruticosa L.
Potentilla monspeliensis L.
Potentilla palustris (L.) Scop.
Potentilla recta L.
Potentilla simplex Michx.
Geum canadense Jacq.
Geum laciniatum Murr.*
Geum strictum Ait.
Geum triflorum Pursh
Agrimonia gryposepala Wallr.
Agrimonia parviflora Ait.
Agrimonia striata Michx.
Rubus allegheniensis Porter
Rubus flagellaris Willd.
Rubus occidentalis L.
Rubus strigosus Michx.
Rubus spp.
Rosa blanda Ait.
Rosa carolina L.
Rosa eglanteria L.*
Rosa palustris Marsh.
Rosa suffulta Greene
Amelanchier arborea (Michx. f.) Fern.
Amelanchier laevis Wieg.
Pyrus communis L.*
Malus coronaria (L.) Mill.*

Malus ioensis (Wood) Bailey
Malus pumila Mill.
Crataegus crus-galli L.
Crataegus mcrosperma Ashe
Crataegus mollis (T. & G.) Scheele
Crataegus pruinosis (Wende.) K. Koch.
Crataegus punctata Jacq.
Crataegus spp.
Prunus americana Marsh.
Prunus lanata (Sudw.) M. & B.
Prunus nigra L.
Prunus pennsylvanica L.
Prunus serotina Ehrh.
Prunus virginiana L.

Leguminosae

Desmanthus illinoensis (Michx.) MacM.
Gymnocladus dioica (L.) K. Koch.
Gleditsia triacanthos L.
Cassia fasciculata Michx.
Cassia nictitans L.*
Baptisia leucantha T. &. G.
Baptisia leucophaea Nutt.
Lupinus perennis L.
Trifolium arvense L.
Trifolium hybridum L.
Trifolium pratense L.
Trifolium procumbens L.
Trifolium repens L.
Melilotus alba Desr.
Melilotus officinalis (L.) Lam.
Medicago lupulina L.
Medicago sativa L.
Hosackia americana (Nutt.) Piper*
Psoralea tenuiflora Pursh
Amorpha canascens L.
Amorpha fruticosa L.
Dalea alopecuroides Willd.*
Petalostemum candidum Michx.
Petalostemum purpureum (Vent.) Rydb.
Tephrosia virginiana (L.) Pers.
Robinia pseudoacacia L.
Astragalus canadensis L.
Desmodium canadense (L.) DC.
Desmodium canescens (L.) DC.
Desmodium dillenii Darl.
Desmodium glutinosum (Muhl.) Wood
Desmodium illinoense Gray
Desmodium marilandicum (L.) DC.
Desmodium nudiflorium (L.) D. C.
Desmodium paniculatum (L.) DC.
Desmodium rigidum (Ell.) DC.*
Desmodium rotundifolium (Michx.) DC.*
Desmodium viridiflorum (L.) Beck.*
Lespedeza capitata Michx.
Lespedeza hirta (L.) Horn.
Lespedeza repens (L.) Bart.
Lespedeza violacea (L.) Britt.
Vicia americana Muhl.
Vicia cracca L.*
Vicia sativa L.
Vicia villosa L.
Lathyrus myritfolius Muhl.*
Lathyrus ochroleucus Hook.
Lathyrus palustris L.
Lathyrus venosus Muhl.
Apios americana Medic.
Strophostyles helvola (L.) Britt.
Strophostyles umbellata (Muhl.) Britt.*
Amphicarpa bracteata (L.) Fern.
Amphicarpa comosa (L.) G. Don.

Geraniaceae

Geranium carolinianum L.
Geranium maculatum L.
Geranium robertianum L.

Oxalidaceae

Oxalis corniculata L.
Oxalis cymosa Small
Oxalis grandis Small*
Oxalis stricta L.
Oxalis violacea L.

Linaceae

Linum sulcatum Riddell

Balsomaceae

Impatiens biflora Walt.
Impatiens pallida Nutt.

Limnanthaceae

Floerkea proserpinacoides Willd.

Rutaceae

Zanthoxylum americanum Mill.
Ptelea trifoliata L.

Simarubaceae

Ailanthus altissima (Mill.) Swingle

Polygalaceae

Polygala incarnata L.
Polygala polygama Walt.
Polygala sanguinea L.
Polygala senega L.
Polygala verticillata L.

Euphorbiaceae

Croton glandulosus L.
Acalypha gracilliens Gray*
Acalypha virginica L.
Euphorbia commutata Engelm.
Euphorbia corollata Pursh
Euphorbia cyparissias L.
Euphorbia dentata Michx.
Euphorbia geyeri Engelm.
Euphorbia humistrata Engelm.*
Euphorbia hirsuta (Torr.) Wieg.*
Euphorbia maculata L.
Euphorbia polygonfolia L.
Euphorbia supina Raf.

Callitrichaceae

Callitriche heterophylla Pursh
Callitriche palustris L.*

Celastraceae

Euonymus atropurpureus Jacq.
Euonymus obovatus Nutt.*
Celastrus scandens L.

Anacardiaceae

Rhus arenaria (Greene) Jones
Rhus glabra L.
Rhus radicans L.
Rhus typhina L.

Staphyleaceae

Staphylea trifolia L.

Aceraceae

Acer nigrum Michx. f.
Acer negundo L.
Acer rubrum L .
Acer saccharum Marsh.
Acer saccharinum L.

Rhamnaceae

Rhamnus lanceolata Pursh
Ceanothus americanus L.
Ceanothus ovatus Desf.*

Vitaceae

Vitis aestivalis Michx.
Vitis riparia Michx.
Vitis vulpina L.
Parthenocissus quinquefolia (L.) Planch.

Tiliaceae

Tilia americana L.

Malvaceae

Malva moschata L.
Malva rotundifolia L.
Callirhoe triangulata (Leav.) Gray
Napaea dioica L.*
Sida spinosa L.
Abutilon theophrasti Medic.
Hibiscus militaris Cav.*

Hypericaceae

Hypericum ascyron L.
Hypericum canadense L.
Hypericum ellipticum Hook.*
Hypericum majus (Gray) Britt.*
Hypericum mutilum L.
Hypericum perforatum L.
Hypericum punctatum Lam.
Hypericum sphaerocarpum Michx.
Hypericum virginicum L.*

Cistaceae

Hudsonia tomentosa Nutt.
Helianthemum canadense (L.) Michx.
Lechea minor L.
Lechea stricta Legg.*
Lechea tenuifolia Michx.
Lechea villosa Ell.*

Violaceae

Viola blanda Willd.*
Viola canadensis L.
Viola conspersa Reich.*
Viola cucullata Ait.
Viola eriocarpa Schw.
Viola fimbriatula Sm.
Viola lanceolata L.*
Viola palmata L.
Viola papilionacea Pursh
Viola pedata L.
Viola pedatifida Don.*
Viola pubescens Ait.
Viola sagittata Ait.
Viola striata Ait.
Viola sororia Willd.

Cactaceae

Opuntia rafinesquii Engelm.

Thymeleaceae

Dirca palustris L.

Lythraceae

Rotala ramosior (L.) Koehne
Peplis diandra Nutt.*
Ammania coccinea Rottb.
Decodon verticillatus (L.) Ell.*
Lythrum alatum Pursh

Onagraceae

Epilobium adenocaulon Hauss.
Epilobium angustifolium L.
Epilobium coloratum Muhl.
Epilobium strictum Muhl.*
Ludwigia palustris (L.) Ell.
Ludwigia polycarpa S. & P.*
Oenothera biennis L.
Oenothera fruticosa L.
Oenothera laciniata Hill.
Oenothera muricata L.*
Oenothera pumila L.
Oenothera rhombipetala Nutt.
Oenothera speciosa Nutt.*
Gaura biennis L.
Circaea latifolia Hill
Circaea alpina L.*

Haloragidaceae

Myriophyllum heterophyllum Michx.
Myriophyllum verticillatum L.*
Proserpinaca palustris L.

Cornaceae

Cornus alternifolia L. f.
Cornus asperifolia Michx.
Cornus obliqua Raf.*
Cornus racemosa Lam.

Cornus rugosa Lam.
Cornus stolonifera Michx.

Araliaceae

Aralia nudicaulis L.
Aralia racemosa L.
Panax quinquefolia L.*

Umbelliferae

Eryngium yuccifolium Michx.
Daucus carota L.
Sanicula canadensis L.
Sanicula gregaria Bickn.
Sanicula marilandica L.
Sanicula trifoliata Bickn.*
Osmorhiza claytoni (Michx.) Clark
Osmorhiza longistylis (Torr.) DC.
Cryptotaenia canadensis (L.) DC.
Berula pusilla (Nutt.) Fern.*
Chaerophyllum procumbens (L.) Crantz.
Zizia aptera (Gray) Fern.
Zizia aurea (L.) Koch.
Taenidia integerrima (L.) Drude
Sium cicutaefolium Gmel.*
Cicuta bulbifera L.
Cicuta maculata L.
Thaspium sylvaticum (Benke) Jones
Thaspium barbinode (Michx.) Nutt.*
Polytaenia nuttallii DC.*
Angelica atropurpurea L.
Heracleum lanatum Michx.
Pastinaca sativa L.

Ericaceae

Chimaphila umbellata (L.) Nutt.*
Pyrola elliptica Nutt.
Pyrola secunda L.*
Monotropa uniflora L.
Arctostaphylos uva-ursi (L.) Spreng.*
Gaylussacia baccata (Wang.) K. Koch.

Primulaceae

Primula mistassinica Michx.
Lysimachia ciliata L.
Lysimachia lanceolata Walt.*
Lysimachia nummularia L.
Lysimachia quadriflora Sims.*
Lysimachia quadrifolia L.
Dodecatheon meadia L.

Oleaceae

Fraxinus americana L.
Fraxinus lanceolata Sarg.
Fraxinus nigra Marsh.
Fraxinus pennsylvanica Marsh.

Gentianaceae

Gentiana andrewsii Griseb.*
Gentiana crinita Froel.*
Gentiana flavida Gray
Gentiana puberula Michx.
Gentiana quinquefolia L.
Menyanthes trifoliata L.*

Apocynaceae

Apocynum androsaemifolium L.
Apocynum cannabinum L.
Apocynum pubescens R. Br.
Apocynum sibericum Jacq.*

Asclepiadaceae

Asclepias amplexicaulis Sm.
Asclepias incarnata L.
Asclepias phytolaccoides Pursh
Asclepias purpurascens L.
Asclepias sullivantii Engelm.*
Ascelpias syriaca L.
Ascelpias tuberosa L.
Ascelpias verticillata L.
Acerates floridana (Lam.) Hitchc.
Acerates lanuginosa Nutt.
Acerates viridiflora (Raf.) Eaton*

Convolvulaceae

Convolulus arvensis L.
Convolulus sepium L.
Convolulus spithamaeus L.
Cuscuta glomerata Choisy*
Cuscuta gronovii Willd.
Cuscuta spp.

Polemoniaaceae

Phlox divaricata L.
Pholx glaberrima L.*
Phlox pilosa L.
Collomia linearis Nutt.
Polemoniam reptans L.

Hydrophyllaceae

Hydrophyllum appendiculatum Michx.
Hydropyhllum canadense L.*
Hydrophyllum virginianum L.
Ellisia nyctelea L.

Boraginaceae

Cynoglossum officinale L.
Lappula echinata Gilib.*
Lappula virginiana (L.) Greene
Lithospermum angustifolium Michx.
Lithospermum arvense L.
Lithospermum canescens (Michx.) Lehm.
Lithospermum croceum Fern.
Lithospermum latifolium Michx.
Onosmodium occidentale Mack.*

Verbenaceae

Verbena hastata L.
Verbena simplex Lehm.*
Verbena stricta Vent.
Verbena urticaefolia L.
Phyla lanceolata (Michx.) Greene

Labiatae

Teucrium canadense L.
Teucrium occidentalis Gray*
Isanthus brachiatus (L.) BSP.
Scutellaria ambigua Nutt.*

Scutellaria galericulata L.*
Scutellaria lateriflora L.
Scutellaria ovata Hill
Scutellaria parvula Michx.
Marrubium vulgare L.*
Agastache nepetoides (L.) Ktze.
Agastache scrophulariaefolia (Willd.) Ktze.
Nepeta cataria L.
Glecoma hederacea Benth.
Physostegia virginianum (L.) Benth.
Prunella vulgaris L.
Leonurus cardiaca L.
Leonurus marrubiastrum L.*
Stachys aspera Michx.
Stachys cordata Ridd.*
Stachys palustris L.
Stachys tenuifolia Willd.
Salvia reflexa Hornem.
Blephilia ciliata (L.) Raf.
Blephilia hirsuta (Pursh) Benth.
Monarda fistulosa L.
Monarda punctata L.
Hedeoma hispida Pursh
Hedeoma pulegioides (L.) Pers.
Clinopodium glabrum (Nutt.) Ktze.
Pycnantheum flexuosum (Walt.) BSP.
Pycnantheum pilosum Nutt.
Pycnantheum virginianum (L.) D. & J.
Lycopus americanus Muhl.
Lycopus rubellus Moench.*
Lycopus uniflorus Michx.
Lycopus virginicus L.
Mentha arvensis L.
Mentha canadensis L.
Mentha citrata Ehrh.*
Mentha piperita L.
Mentha spicata L.

Solonaceae

Solanum carolinense L.
Solanum dulcamara L.
Solanum nigrum L.
Solanum rostratum Dunal
Physalis heterophylla Nees.
Physalis pubescens L.
Physalis subglabrata M. & B.
Physalis virginiana Mill.*
Datura stramonium L.

Scrophulariaceaeae

Verbascum thapsus L.
Chelone glabra L.
Penstemon hirsutus (L.) Willd.
Penstemon digitalis Nutt.
Penstemon pallidus Small*
Scrophularia lanceolata Pursh
Scrophularia marilandica L.
Linaria canadensis (L.) Dum.
Linaria vulgaris Mill.
Lindernia dubia (L.) Pennell
Gratiola virginiana L.*
Mimulus alatus Ait.
Mimulus geyeri Torr.*
Mimulus ringens L.
Veronicastrum virginicum (L.) Farw.
Veronica americana Schw.
Veronica anagallis-aquatica L.*
Veronica arvensis L.
Veronica peregina L.
Veronica persica Poir.*
Veronica virginica L.
Synthyris bullii (Eaton) Hell.
Aureolaria flava (L.) Farw.
Aureolaria grandiflora (Benth) Pennell
Aureolaria pedicularia (L.) Raf.
Gerardia asper Dougl.*
Gerardia skinneriana Wood*
Gerardia tenuifolia Vahl.
Otophylla auriculata Nutt.*
Castilleja coccinea (L.) Spreng.
Pedicularis canadensis L.
Pedicularis lanceolata Michx.

Lentibulariaceae

Utricularis vulgaris L.

Orobanchaceae

Orobanche uniflora L.*

Phrymaceae

Phryma leptostachya L.

Plantainaceae

Plantago aristata Michx.
Plantago lanceolata L.
Plantago major L.*
Plantaga purshii R. & S.
Plantago rugelii Dcne.

Rubiaceae

Cephalanthus occidentalis L.
Diodia teres Walt.
Galium aparine L.
Galium asperellum Michx.
Galium boreale L.
Galium circaezans Michx.
Galium palustre L.*
Galium trifidum L.
Galium triflorum Michx.

Caprifoliaccae

Sambucus canadensis L.
Viburnum acerifolium L.
Viburnum affine Bush
Viburnum prunifolium L.
Viburnum rafinesquianum Schult.
Viburnum trilobum Marsh.
Symphoricarpos occidentalis Hook.
Symphoricarpos rivularis Suksd.*
Lonicera dioica L.*
Lonicera flava Sims.
Lonicera prolifera (Kirsch.) Rehr.
Diervilla lonicera Mill.
Triosteum aurantiacum Bickn.
Triosteum perfoliatum L.
Adoxa moschatellina L.*

Valerianaceae

Valeriana edulis Nutt.

Cucubitaceae

Echinocystis lobata (Michx.) T. & G.
Sicyos angulatus L.*

Campanulaceae

Campanula americana L.
Campanula aparinoides Pursh*
Campanula rotundifolium L.
Campanula trachelium L.*
Specularia perfoliata (L.) A. DC.

Lobeliaceae

Lobelia cardinalis L.
Lobelia inflata L.
Lobelia leptostachys A. DC.*
Lobelia siphilitica L.
Lobelia spicata Lam.

Compositae

Iva ciliata Willd.
Iva xanthifolia Nutt.*
Ambrosia coronopifolia T. & G.*
Ambrosia elatior L.
Ambrosia trifida L.
Xanthium canadense Mill.
Xanthium commune Britt.
Vernonia fasciculata Michx.
Vernonia missurica Raf.
Eupatorium altissimum L.
Eupatorium maculatum L.
Eupatorium perfoliatum L.
Eupatorium purpureum L.
Eupatorium rugosum Houtt.
Eupatorium serotinum Michx.
Kuhnia eupatorioides L.
Liatris aspera Michx.
Liatris bebbiana Rydb.
Liatris cylindracea Michx.*
Liatris spicata (L.) Willd.*
Grindelia squarrosa (Pursh) Dunal*
Chrysopsis villosa (Pursh) Nutt.*
Solidago altissima L.
Solidago canadensis L.
Solidago gilvocanescens Rydb.
Solidago glaberrima Martens
Solidago hirtella (Greene) Bush*
Solidago hispida Muhl.
Solidago juncea Ait
Solidago latifolia L.
Solidago media (Greene) Bush
Solidago nemoralis Ait.
Solidago riddellii Frank
Solidago rigida L.
Solidago rugosa Mill.*
Solidago serotina Ait.
Solidago speciosa Nutt.
Solidago ulmifolia Muhl.
Solidago uniligulata (DC.) Porter*
Boltonia asteroides (L.) L'Her.*
Aster anomalus Engelm.
Aster azurus Lindl.
Aster cordifolius L.
Aster drummondii Lindl.
Aster dumosus L.*
Aster ericoides L.
Aster interior Wieg.*
Aster junceus Ait.
Aster laevis L.
Aster lateriflorus (L.) Britt.
Aster linariifolius L.
Aster macrophyllus L.*
Aster novae-angliaea L.
Aster oblongifolius Nutt.*
Aster paniculatus Lam.
Aster pilosus Willd.
Aster prealtus Poir.
Aster prenanthoides Muhl.
Aster ptarmicoides (Nees.) T. & G.
Aster sagittifolius Wed.*
Aster salicifolius Lam.
Aster sericeus Vent.*
Aster shortii Lindl.
Aster umbellatus Mill.
Aster vimineus Lam.*
Erigeron annuus (L.) Pers.
Erigeron canadensis L.
Erigeron divaricatus Michx.*
Erigeron philadelphicus L.
Erigeron pulchellus Michx.
Erigeron strigosus Muhl.
Antennaria fallax Greene
Antennaria neglecta Greene.*
Antennaria neodioica Greene*
Antennaria plantaginifolia Hook.
Gnaphalium obusifolium L.
Gnaphalium uliginosum L.*
Polymnia canadensis L.
Silphium integrifolium Michx.
Silphium laciniatum L.
Silphium perfoliatum L.
Silphium terebinthinaceum Jacq.
Parthenium integrifolium L.
Heliopsis helianthoides (L.) Sweet
Eclipta alba (L.) Hassk.
Rudbeckia hirta L.
Rudbeckia laciniata L.
Rudbeckia subtomentosa Pursh*
Rudbeckia triloba L.
Brauneria pallida (Nutt.) Britt.
Ratibida pinnata (Vent.) Barnh.
Galinsoga ciliata (Raf.) Blake
Helianthus annuus L.
Helianthus decapetalus L.
Helianthus divaricatus L.
Helianthus grosseserratus Martens
Helianthus maximiliani Schrad.*
Helianthus occidendentalis Riddell
Helianthus petiolaris Nutt.*
Helianthus rigidus (Cass.) Desf.
Helianthus strumosus L.
Helianthus tuberosus L.*

Coreopsis lanceolata L.
Coreopsis palmata Nutt.
Bidens aristosa (Michx.) Britt.
Bidens comosa (Gray) Wieg.
Bidens connata Muhl.*
Bidens coronata (L.) Britt.
Bidens discoidea (T. & G.) Britt.*
Bidens frondosa L.
Helenium autumnale L.
Dyssodia paposa (Vent.) Hitchc.*
Archillea millefolium L.
Chrysanthemum leucanthemum L.
Anthemis cotula L.
Tanacetum vulgare L.
Artemisia annua L.*
Artemisia biennis Willd.*
Artemisia canadensis Michx.*
Artemisia caudata Michx.
Artemisia dracunculoides Pursh*
Artemisia gnaphaloides Nutt.
Artemisia serrata Nutt.*
Cacalia atriplicifolia L.
Cacalia muhlenbergii (Sch-Bip.) Fern.
Cacalia suaveolens L.
Cacalia tuberosa Nutt.
Erechtites hieracifolia (L.) Raf.*
Senecio aureus L.
Senecio balsamitae Muhl.
Senecio obovatus Muhl.*
Arctium minus (Hill) Bern.
Cirsium altissimum (L.) Spreng.
Cirsium arvense (L.) Scop.
Cirsium dicolor (Muhl.) Spreng.
Cirsium muticum Michx.
Cirsium undulatum (Muhl.) Spreng.*
Cirsium vulgare (Savi) Airy-Shaw
Tragopogon pratensis L.
Krigia biflora (Walt.) Blake
Krigia virginica (L.) Willd.
Cichorium intubus L.
Lactuca canadensis L.
Lactuca biennis (Moench) Fern.*
Lactuca floridana (L.) Gaertn.
Lactuca pulchella (Pursh) DC.*
Lactuca sagittifolia Ell.*
Lactuca scariola L.
Lactuca villosa Jacq.*
Sonchus arvensis L.
Sonchus asper (L.) Hill*
Sonchus oleraceus L.
Prenanthes alba L.
Prenanthes altissima L.*
Prenanthes aspera Michx.
Prenanthes cripidinea Michx.*
Hieracium aurantiacum L.*
Hieracium canadense Michx.
Hieracium gronovii L.
Hieracium longipilum Torr.*
Hieracium scabrum Michx.*
Agoseris cuspidata (Pursh) Steud.*
Taraxacum vulgare (Lam.) Schrank
Taraxacum laevigatum (Willd.) DC.

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APPLICATIONS OF SPECTROPHOTOMETRIC METHODS TO PROBLEMS OF CHEMICAL ANALYSIS IN THE STUDY OF PLANT PHYSIOLOGY

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In the course of a study of the effect of soil and other environmental factors on the development, growth, and composition of cereal grasses, it was found necessary to carry out a large number of analyses on samples of soil and of plant tissues. Standard macro quantitative procedures were used in many instances, but limitations in the size of the samples frequently made it necessary to turn to semi-micro methods. Colorimetric methods using a spectrophotometer were found to be of great value. The speed and accuracy of spectrophotometric methods have led the author to abandon the usual macro procedures in many instances. The purpose of the present note is to call to the attention of plant physiologists the great usefulness of these procedures.

A survey of the literature shows that many colorimetric procedures are available. Reitemeier (14) published a set of methods for the semi-micro-analysis of saline salt solutions. Peech (12) outlined methods for the micro-determination of exchangeable bases in soils. Wall (16) developed micromethods for the determination of inorganic constituents of plants. Lindner (8) has also outlined colorimetric methods for the rapid analysis of the common inorganic constituents of plant tissue. Parks, Hood, Hurwitz and Ellis (11) set up a systematic procedure for quantitative microdetermination of twelve elements in plant tissue. Wolf (18) described several rapid photometric methods for use on plant tissues. Numerous other methods are also available for the analysis of plant material.

Many colorimetric methods have been tried in the laboratory over a period of several years for the analysis of soils and plant materials. The present paper does not intend to describe the details of the methods used, but merely to suggest a few of the most generally applicable types of analyses possible through the use of a spectrophotometer. All the methods mentioned have been thoroughly tested by experience and they are especially valuable because of their precision and the comparative ease of execution. A Coleman Model 11 Universal Spectrophotometer was used for all determinations. Photometric calibration curves were prepared from standards, but it was found advisable to run a series of standards through the colorimetric procedure with each day's run.

COLORIMETRIC METHODS OF SOIL ANALYSIS

Phosphorus fractions.—Bray and Dickman (2) described procedures for the quantitative determination of four fractions of phosphorus adsorbed by the colloidal material in the soil. The phosphorus in the various types of extracts was determined colorimetrically by the method of Dickman and Bray (4) using the Kurtz (7) modification to suppress interference by the fluoride ions. A wave length of 7750 A was used to-

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gether with a PC-5 filter. Standards were prepared containing 0.005 to 0.065 mgm. of phosphorus per 50 ml.

Potassium.—Exchangeable potassium was determined in the ammonium acetate leachate obtained during the base-exchange procedure as described by Noggle and Wynd (10). After evaporation of the leachate, it was ignited and taken up with nitric acid, and the potassium determined by the method of Wander (17). A wave length of 4250 A was used with a PC-4 filter. The standards contained 1 to 7 mgm. of potassium per 100 ml.

Sodium. — Exchangeable sodium in the ammonium acetate leachate, obtained by the conventional base-exchange procedure (10), or water-soluble sodium, was determined colorimetrically as described by Reitemeier (14). A wave length of 4200 A was used with a PC-4 filter. The sodium standards contained 0.025 to 0.25 mgm. of sodium.

COLORIMETRIC METHODS FOR THE ANALYSIS OF PLANT ASH

The inorganic constituents in plant tissues were obtained in solution by wet ashing with perchloric and nitric acid; 0.5 to 1.0 gm. of dried plant material was treated with 10 ml. of water, 10 ml. of concentrated nitric acid and 10 ml. of 72 percent perchloric acid. The beaker, containing the plant material, was covered with a watch glass and the contents boiled gently on a hot plate until the organic matter was destroyed. After cooling, the watch glass and sides of the beaker were washed down with distilled water. The beaker without the watch glass was then returned to the hot plate and the contents evaporated to dryness. The residue was taken up with 5 ml. of 1:4 HCl and 25 ml. of distilled water. The solution was then filtered to remove the silica which was dehydrated by the perchloric acid. The filtrate was made up to 100 ml. volume and aliquots used for subsequent analysis.

Magnesium.—The method of Reitemeier (14) was used to determine magnesium. An aliquot of the ashed solution was transferred to a 15 ml. centrifuge tube and the calcium precipitated as the oxalate. The filtrate and washings from the calcium oxalate precipitate were made up to 25 ml. volume and an aliquot taken for the magnesium determination. The magnesium was precipitated as magnesium ammonium phosphate hexahydrate, and the amount estimated from the phosphorus content. Solutions containing 0.01 to 0.08 mgm. of magnesium were used as standards. A wave length of 5400 A was used with a PC-4 filter.

Potassium. — The cobaltinitrite procedure, using the nitroso R-salt, as outlined by Peech (12) was used. A wave length of 5500 A in connection with a PC-4 filter was used. Standards contained 0.1 to 1.8 mgm. of potassium.

Phosphorus. — The colorimetric phosphate method of Dickman and Bray (4) was used. A wave length of 7750 A and a PC-5 filter were used. The standards contained 0.005 to 0.065 mgm. of phosphorus.

Manganese.—The periodate method as described by Peech (12) was found to be very satisfactory. A wave length of 5350 A and a PC-4 filter were used. The standards contained 0.005 to 0.20 mgm. of manganese.

Iron.—The method of Hummel and Willard (5) as modified by the AOAC (1) was used. A wave length of 5100 A and a PC-4 filter were used. Solutions containing 0.01 to

0.09 mgm. of iron were used as standards.

COLORIMETRIC METHODS FOR NITROGEN

Boiling water extracts were made of the dried plant material. Nitrate, ammonia, alpha-amino, and amide nitrogen were determined in the extract. The scheme of analysis as outlined by Schlenker (15) was used. All fractions, except nitrate nitrogen, were determined by Nesslerization of ammonia after alkaline aspiration.

Ammonia nitrogen. — The ammonia, after being aspirated from an alkaline solution into 0.1 N HCl, was determined colorimetrically by Nessler's reagent. The Nessler reagent was prepared according to Koch and McMeekin (6). A wave length of 5000 A was used with a PC-4 filter. The standards contained 0.1 to 1.0 mgm. of ammonia nitrogen.

Nitrate nitrogen.—The nitrate nitrogen was determined colorimetrically by the phenol-disulphonic acid method as outlined by Schlenker (15). A wave length of 4100 A with a PC-4 filter was used. 0.01 to 4.0 mgm. of nitrate nitrogen were used as standards.

METHODS FOR ASCORBIC ACID AND CHLOROPHYLL

Ascorbic acid.—The ascorbic acid was extracted by disintegrating the plant material in a Waring Blendor. The extracting medium was 0.5 percent oxalic acid as suggested by Ponting (13). The ascorbic acid was determined by the method of Morell (9). A wave length of 5200 A was used with a PC-4 filter. Standards containing 1 to 14 micrograms of ascorbic acid per ml. were used.

Chlorophyll.—The chlorophyll was determined by the method of Comar, Benne, and Buteyn (13). The chlorophyll was extracted by disintegrating the tissue in 85 percent acetone with a Waring Blendor. A wave length of 6600 A was used with a PC-5 filter.

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CHEMISTRY

ELECTRONS AND REDOX EQUATIONS

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We are told that electrons are real entities but of such nebulosity that they can best be characterized by a mathematical equation. Yet we grass-roots chemists glibly talk of electrons as if they were little hard particles with a definite volume, shape and smooth surface. In fact it seems to me that we use them about like one would a coinage of negative pennies for settling interatomic debts. With such usage a few errors have crept in which I should like to point out.

It is commonly taught and correctly so, I believe, that oxidation represents a loss of electrons while reduction represents a gain. This is obvious in the case of a piece of zinc metal used as the negative pole of voltaic cell:

$$Zn \longrightarrow Zn^{++} + 2e.$$

The zinc metal gains two points in valence and loses two electrons. While at the positive pole, let us assume that cupric ions are accepting electrons to form copper metal:

$$Cu^{++} + 2e \longrightarrow Cu.$$

(Of course, in this day and age of precise formulation we understand that all ions in solution are solvated and that $Zn(H_2O)_4^{++}$ and $Cu(H_2O)_4^{++}$ would more correctly express the cations involved.)

The ion-electron method of balancing redox equations has been widely accepted. We shall use this method to trace the migration of electrons during the oxidation of hydrochloric acid by $KMnO_4$. The unbalanced orthodox equation is:

$$KMnO_4 + HCl \longrightarrow KCl + MnCl_2 + Cl_2 + H_2O.$$

The ion-electron method recognizes that any permanganate and any soluble chloride in the presence of acid will react in a similar fashion. Therefore it is actually a reaction of the MnO_4 ion, the H^+ ion and the Cl^- ion. The K^+ ion is an innocent bystander and may be omitted from such an equation. The permanganate ion is obviously the oxidant and obviously forms manganous ions:

$$MnO_4^- \longrightarrow Mn^{++}.$$

The oxygen in the MnO_4^- must form H_2O which accounts for the need of acid or H^+. In the absence of acid, MnO_2 is formed, showing the importance of H^+ in the equation. (Of course H^+ is more correctly written H_3O^+ but H^+ is used for simplicity.) Now we are ready to continue with our balancing:

$$H^+ + MnO_4^- \longrightarrow Mn^{++} + H_2O$$

The four oxygens would yield $4H_2O$ which would call for $8H^+$:

$$5e + 8H^+ + MnO_4^- \longrightarrow Mn^{++} + 4H_2O$$

The reductant equation is much simpler:

$$2Cl^- \longrightarrow Cl_2 + 2e.$$

Here we have added two electrons to the right to make that side have two minus charges as the left already had.

Next, since electrons obey the law of conservation of matter we must have the same number of electrons leaving the reductant as are taken up by the oxidant. The lowest common multiple of 2 and 5 is 10. The

oxidant equation is multiplied by 2 and the reductant by 5:

$$2\,(5e + 8H^+ + MnO_4^- \longrightarrow Mn^{++} + 4H_2O)$$

$$5\,(2Cl^- \longrightarrow Cl_2 + 2e)$$

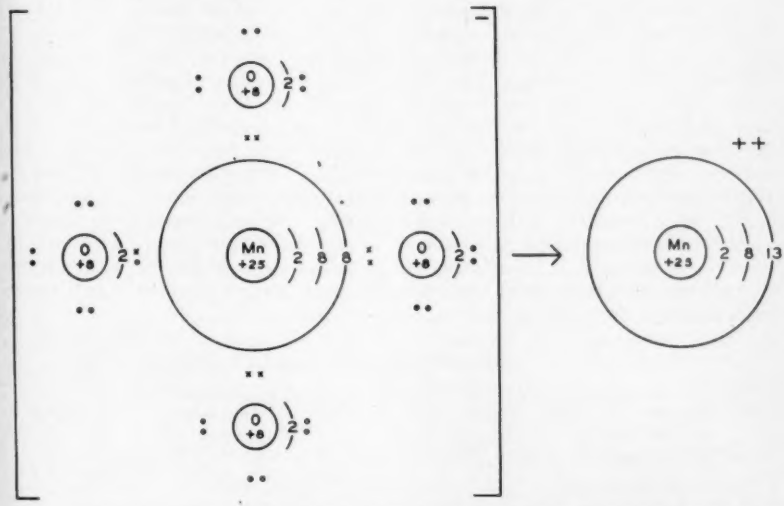
or

$$10e + 16H^+ + 2MnO_4^- \longrightarrow 2Mn^{++} + 8H_2O$$

$$10Cl^- \longrightarrow 5\,Cl_2 + 10e$$

$$16H^+ + 10Cl^- + 2MnO_4^- \longrightarrow 2Mn^{++} + 5Cl_2 + 8H_2O$$

When this same equation is balanced by the valence change method one finds that Mn loses 5 points of valence, going from +7 in $KMnO_4$ to +2 in $MnCl_2$ and that the 5 points loss is numerically equal to the number of electrons gained BY THE OXIDANT in the ion-electron method just shown. Also each Cl gains one point in valence. Now some teachers and some texts* argue that a loss in valence is a gain of electrons so that we can say if the Mn loses 5 points of valence it thereby gains 5 electrons. However our ion-electron oxidant equation shows that *the MnO_4^- ion in the presence of the H^+* gains the 5 electrons and *not just the manganese atom.* Let us study the electronic structure of the two ions involved:



One can see that the Mn nucleus in the permanganate ion is surrounded by shells of 2, 8, and 8 electrons and is sharing 8 more with 4 oxygens making a total of 26 electrons while the manganous ion has shells 2, 8, and 13 electrons making a total of 23 (it having become deficient two electrons from a metallic manganense atom with 25 electrons and so has a charge of +2). It is therefore difficult to see how anyone can say that the Mn, itself, gains 5 electrons but it is easy to demonstrate that if each pair of H^+ ions removes an oxygen from the permanganate, 8 valence electrons will be required for each of the four H_2O molecules

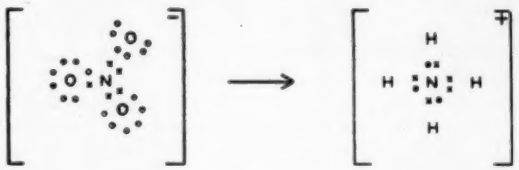
*See reference No. 4a for an example of this misconception.

formed as well as 2 each for the inner shell. With the original 26 electrons surrounding the Mn nucleus and the 6 valence electrons of each of the 4 oxygen (and the 2 inner shell electrons of the oxygens) we have 26 + 32 or 58 electrons supplied by the MnO_4^- but the $4H_2O$ required 10 each and the Mn^{++} ion 23 or a total of 63. Thus 5 electrons must be added from an outside source (reductant.) But the 5 electrons are used up by the reactants on the left working together and not by the manganese alone.

A simpler but just as interesting case is the reduction of nitrate ion in acid solution to ammonium ion:

$$8+10H^+ + NO_3^- \longrightarrow NH_4^+ + 3H_2O$$

The electronic configuration here can be limited to the valence electrons since no transition element is involved:



It will be seen that in each case the N atom is surrounded by 8 electrons. The ion-electron equation shows that 8 electrons are gained by the *10 H^+ and the NO_3^-* and the valence change method will show that 8 points in valence are lost by the nitrogen atom, which careless ones translate into a gain of 8 electrons *by the nitrogen*.

Therefore we should reject the method sometimes taught of balancing Redox equations which leads one to say "N loses 8 points in valence so it gains 8 electrons." One should not mix up valence-change, an 1880 concept, with a modern concept like electrons.

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SOME TRISUBSTITUTED BENZOTRIFLUORIDES*

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A number of highly fluorinated aliphatic compounds have been known for some time, especially, some of the chlorofluoro derivatives of methane and ethane. Due to their unique properties they have found commercial application as refrigerants, as propellants in "bug bombs," as gaseous and liquid dielectrics, and in the synthesis of some very unusual polymers. These discoveries and applications warrant research in other types of compounds. Almost immediately the field of aromatic compounds suggests itself. Very few polyfluorides of such simple molecules as benzene and toluene have been described in the literature. The synthesis of two difluorobenzotrifluorides by Finger and Reed[1] in the Survey laboratories immediately brought requests for samples and for further information on these and other aromatic compounds. This paper represents a preliminary report on some of the intermediate compounds studied in trying to find an appropriate synthesis for a trifluorobenzotrifluoride.

The synthesis of higher fluorinated aromatic compounds presents two problems; (1) the usual fluorine substitution reactions tend to be inoperative as the degree of substitution increases, and (2) it is necessary to know the exact structure of the final compound in order to evaluate it properly. Ordinarily the second problem is solved if the structure of the compound just preceding the introduction of a fluorine atom is definitely known. These facts are, more or less, illustrated in this preliminary report.

As a first approach to a probable synthesis of a trifluorobenzotrifluoride, 2-acetylamino-5-fluorobenzotrifluoride (I) was used as the starting compound. This compound was available in the Survey laboratories as a result of some previous work[1].

The nitration of (I) followed by hydrolysis of the acetyl group gave 2-amino-3-nitro-5-fluorobenzotrifluoride (III) . This was the compound desired although on a theoretical basis two other isomers could be formed, namely, the nitro group could have entered also into the 4 or 6 positions. These isomers were not isolated although they may have been present in small amounts. The structure of compound (III) was established by conversion to 2, 3-diphenyl-6-fluoro-8-trifluoromethylquinoxaline (V). After having established the structure of 2-amino-3-nitro-5-fluorobenzotrifluoride (III), it appeared that this nitroamine may be the basis for the synthesis of 2,3,5-trifluorobenzotrifluoride.

Attempts to apply the Schiemann reaction, in the usual way, to 2-amino-3-nitro-5-fluorobenzotrifluoride (III) so as to obtain 2,5-difluoro-3-nitrobenzotrifluoride failed. The nitroamine appears to be only slightly basic although it forms an amine hydrochloride in concentrated hydrochloric acid; the hydrochloride can also be formed in absolute ether by passing in dry hydrogen chloride. Indications are that diazotization did take place; however, when

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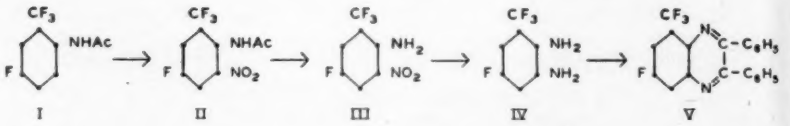

sodium fluoborate was added a precipitate of sodium chloride and sodium fluoborate was formed.

Although these results did not achieve the original objective, the nitration data is significant in predicting the results which may be obtained in nitrating 2,5-difluorobenzotrifluoride. The orientation factors are, more or less, the same thus lending credence to the formation, of 2,5-difluoro-3-nitro-benzotrifluoride as the chief product. The nitration of 2,5-difluorobenzotrifluoride gave a nitro compound and its composition was established through the acetyl derivative of the amine resulting from reduction. Therefore, it is possible to assign a structure with some supporting evidence even though a more positive proof is necessary. The nitro compound is being studied further as to its structure and properties.

The authors are indebted to Dr. F. H. Reed, chief chemist, for suggestions, and to Mr. H. S. Clark, microanalyst, for the analyses in this investigation.

EXPERIMENTAL

2-Amino-3-nitro-5-fluorobenzotrifluoride (III).—Twenty grams of 2-acetylamino-5-fluorobenzotrifluoride[1] (I) was dissolved in a mixture of 150 g. of concentrated sulfuric acid and 30 g. of glacial acetic acid at room temperature. After cooling to 10°, a solution of 12.6 g. of fuming nitric acid (sp. gr. 1.49-1.5) in 25 g. of concentrated sulfuric acid was added slowly with stirring, and the temperature maintained at 10-20° for ninety minutes. The reaction mixture was poured slowly into an ice-water mixture giving a white precipitate. After filtering and drying, the yield of crude product was 17 g. This crude product was found to be chiefly 2-acetylamino-3-nitro-5-fluorobenzotrifluoride (II) upon recrystallizing a sample from 50 percent aqueous ethanol. The crude material was heated on a water bath for one hour with 50 cc. of concentrated sulfuric acid, and poured into an ice-water mixture giving the crude nitroamine as a yellow precipitate. After filtering and drying, recrystallization from 60 percent aqueous ethanol gave 11.5 g. (57 percent) of 2-amino-3-nitro-5-fluorobenzotrifluoride (III) as yellow needles, m.p. 68-69°.

Anal. Calculated for $C_7H_4F_4N_2O_2$: C, 37.51; H, 1.8; N, 12.50. Found: C, 37.63; H, 1.85; N, 12.56.

The acetyl compound (II) upon recrystallization from 50 percent aqueous ethanol gave white needles, m.p. 179.5-180°.

Anal. Calculated for $C_9H_6F_4N_2O_3$: C, 40.61; H, 2.27; N, 10.53. Found: C, 40.70; H, 2.26; N, 10.45.

2,3-Diphenyl-6-fluoro-8-trifluoromethylquinoxaline (V).—To a refluxing solution of 2 g. of 2-amino-3-nitro-5-fluorobenzotrifluoride (III) in 100 cc. of 50 percent aqueous acetic acid, 6 g. of powdered zinc was added in small portions. After the mixture was light yellow in color, the unreacted zinc was removed by filtration. The 2,3-diamino-5-fluorobenzotrifluoride (IV) was not isolated.

To the filtrate was added slowly, a warm solution containing 30 cc. of 40 percent aqueous sodium bisulfite, 3 g. of benzil, and 40 cc. of ethanol. The yellow flocculent precipitate which formed was removed by filtration, washed, and dried. Recrystallization from methanol gave 2,3-diphenyl-6-fluoro-8-trifluoromethylquinoxaline (V) as white needles, m.p. 133-133.5°. The formation of the quinoxaline proved the adjacency of the nitro and amino groups in III.

Anal. Calculated for $C_{21}H_{12}F_4N_2$: C, 68.48; H, 3.28; N, 7.61. Found: C, 68.46 H, 3.28; N, 7.74.

Diazotization of 2-Amino-3-nitro-5-fluorobenzotrifluoride (III).—Attempts were made to diazotize 2-amino-3-nitro-5-fluorobenzotrifluoride (III) under a variety of conditions. The amine hydrochloride may be formed in concentrated hydrochloric acid or by dissolving the nitroamine in absolute ether and passing in anhydrous hydrogen chloride. In a concentrated hydrochloric acid solution, the amine hydrochloride appears to diazotize slowly with sodium nitrite to give a clear solution. Upon the addition of a strong sodium fluoborate solution, a white precipitate of inorganic salt (probably sodium chloride or sodium fluoborate) was formed. Diazotization with nitrosyl sulfuric acid in the presence of phosphoric acid[2] or glacial acetic acid[3] or 60 percent fluoboric acid failed to give a diazonium fluoborate.

2,5-Difluoro-3(?)-nitrobenzotrifluoride.—To a mixture of 40 cc. of fuming sulfuric acid (40 percent SO_3) and 19.3 g. of fuming nitric acid (sp. gr. 1.49-1.5), 18.3 g. of 2,5-difluorobenzotrifluoride was added at such a rate with stirring that the temperature was maintained at 50° for ninety minutes. The entire reaction mixture was poured into an ice-water mixture, and the crude nitro compound was isolated as a heavy yellow oil. The crude yield was 14.8 g. or 62 percent. A preliminary fractional distillation showed that 2,5-difluoro-3(?)-nitrobenzotrifluoride boils about 191-192° or 91.5-92.5°/19 mm. The sample was not pure indicating the possible presence of isomers and also a trace of a dinitro derivative.

A small sample of the crude nitro compound was reduced with iron filings in an ammonium chloride (0.78 N) solution[4] to the amine. The amine was isolated as an oil, and converted to the acetyl derivative by the usual method. Recrystallization from high-boiling petroleum ether gave 2,5-difluoro-3(?)-acetylaminobenzotrifluoride as white needles, m.p. 104.5-105.5°.

Anal. Calculated for $C_9H_6F_5NO$: C, 45.20; H, 2.53; N, 5.86. Found: C, 45.33; H, 2.43; N, 5.82.

SUMMARY

2-Amino-3-nitro-5-fluorobenzotrifluoride was synthesized from 2-acetylamino-5-fluorobenzotrifluoride.

Attempts to convert 2-amino-3-nitro-5-fluorobenzotrifluoride to 2,5-difluoro-3-nitrobenzotrifluoride by the Schiemann reaction failed.

The nitration of 2,5-difluorobenzotrifluoride gives a nitro compound which is probably 2,5-difluoro-3-nitrobenzotrifluoride.

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THE ELECTRON MICROSCOPE AS A TOOL IN CHEMICAL RESEARCH

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The electron microscope has become firmly established as a research instrument in many of the leading laboratories in this country since its introduction just a few years ago. Much research has continuously been done on the instrument itself. Most of the early research involving the instrument was, of course, of an exploratory nature in order to ascertain just what it could do. In very recent times, however, the electron microscope has assumed an important position as a research tool and has in several instances become of use in routine control work of a less fundamental nature. The two main advantages of the electron microscope over the conventional optical microscope are the large useful magnification and the great depth of focus which the new instrument makes possible.

In order for the eye to see an object, its image must subtend an angle of at least 1.4 minutes at the eye. Since the average person can not focus his eye on anything closer than ten inches, it may be derived that the smallest object which can be seen by the unaided eye is 0.1 millimeter.

It was shown some years ago by Abbe and others that a microscope, no matter how perfect it may be, can not separate two points at a distance apart of less than about one-half the wave length of the light. This means that a microscope using visible light can not resolve two points closer together than 2000 angstrom units. In view of this fact it follows that a manification of 0.1 mm. ÷ 2000 A°, or 500 times, is the maximum useful magnification of the optical microscope; this simply means that at a magnification of 500 times the maximum of detail is visible. Of course it is often convenient to use magnifications two or three times greater than that simply to ease eye-strain. Because ultra-violet light has a wave-length approximately one-half that of visible light, the closest proximity of two points for resolution in an ultra-violet microscope is about one-half that for a visible light microscope, and the corresponding maximum useful magnification is about 1000 diameters.

The depth of focus is inversely proportional to the numerical aperture of a lens. Glass optical lenses may have a numerical aperture of about one, with a corresponding depth of focus of 0.04 microns.

In order to increase the available useful magnification it was necessary to find some type of light-beam with a still shorter wave length. The development of the field of electron optics has fulfilled this need. The wave length of an electron beam was shown to be dependent upon the accelerating voltage, and to have a value of 0.05 angstrom units for a sixty kilovolt beam. Furthermore, axially symmetrical electromagnetic and electrostatic fields were both found to be satisfactory as lenses for an electron beam. Thus came the electron microscope.

The numerical aperture of an electron lens is considerably less than that of a glass optical lens. This decrease in numerical aperture is a

factor tending to decrease the resolving power, yet it increases the depth of focus. The very short wave length more than makes up for the effect of the numerical aperture on the resolving power, with the result that the electron microscope has a depth of focus of 1.5 microns and a maximum useful magnification of nearly one-hundred thousand.

The electron microscope itself is strictly analogous to a conventional compound light microscope. Each type of instrument has a light source, a condenser lens to line up the light beam on the specimen, a specimen chamber, an objective lens, a projector lens or an eye-piece, and some means for observing or recording the image. In the light microscope the lenses are of glass, the light source is of visible light and the observation is directly by eye or on a photographic plate; in the electron microscope the light source is a hot filament boiling off electrons while the lenses are either electrostatic or electromagnetic fields, and the observation is visually of the image on a fluorescent screen or may be on a photographic plate.

The magnification of an electron lens is goverened by two factors, the speed of the electrons going through and the strength of the lens field. These factors are in turn governed by the electron beam accelerating potential and the current passing through the lens coil in an electromagnetic instrument. Therefore these quantities must be kept perfectly constant; electronic regulation provides a consistancy of within 0.005 percent. In the electrostatic instrument these two factors affect the lens oppositely so that slight variations in operating potentials do not affect the lens operation. Therefore precise voltage and current regulation is not necessary in the electrostatic instrument. However, the better results have been obtained with the electromagnetic instrument; nevertheless both systems are in fairly wide use.

Because electrons are widely scattered by air, the electron microscope must be kept evacuated during operation to about 10^{-4} millimeters. A mechanical forepump and an oil diffusion pump are continuously applied to the microscope column during operation.

The usefulness of the electron microscope has been increased by further development in instrumentation within the field of electron optics. Several models of microscope have been built by manufacturers. A small instrument is available for many control purposes, using a constant magnification and not having the versatility of a more elaborate instrument. Experimental models with higher accelerating potentials have been constructed in a few commercial and university laboratories, and a scanning instrument for studying surfaces of electron opaque materials has been investigated on an experimental basis. It was a logical development to combine electron diffraction apparatus with the electron microscope, and such dual apparatus is commercially available.

One of the more promising allied developments in the field of electron optics is the electron microanalyzer. It makes possible the chemical identification of an extremely minute section of a specimen. An electron probe is directed onto the desired portion of the specimen, the electrons then losing energy in accordance with the substance which they hit. The beam, after passing through the specimen, is magnetically spread out into its constituent energy portions, which may then be recorded photographically. The resultant spectrum reveals the chemical iden-

tity of the elements which were encountered by the electron probe. It will be possible to combine this technique with the electron microscope so that the desired portion of the specimen may be selected visually.

The scientific literature of the past few years has contained many review articles of electron microscopy, and it has also contained many articles discussing specific applications of electron microscopy. A very excellent general bibliography of the subject has been prepared by C. Marton and S. Sass, J. App. Phys., *14*, 522 (1943) and ibid *15*, 575 (1944). It is the purpose of this present article to give several typical examples of the use of this new instrument within the fields of chemistry. These applications are not intended to be thoroughly discussed, yet they are intended to be thorough enough to illustrate specific examples of the use of the electron microscope. Each of the three applications described has been or will be presented in a more complete form in the literature, and all have been done at the University of Illinois under the direction of Professor G. L. Clark. In each case the electron microscope has been used to complete or substantiate other means of investigation, and is not used as an entity in itself.

CARBON BLACKS AS USED IN DRY CELL MANUFACTURE

One of the more important ingredients which goes into the manufacture of a dry cell is carbon black, which is a part of the manganese dioxide mixture forming the body of the cell. A thorough study of the requirements for such a carbon black has been made by use of the electron microscope in conjunction with x-ray diffraction techniques. (J. N. Mrgudich, R. C. Clock. Electrochemical Society, 86th General Meeting, Oct. 1944, PrePrint 86-29).

The need for such a study became apparent in the early years of this war, when the usual type of acetylene black became difficult and, in some cases, impossible to obtain. The conclusions of this study may be enumerated as follows.

1. A suitable black must have particles that are adequately conductive; this shows up in the x-ray pattern, which must show at least a partial graphitization.

2. Surface forces determining dispersibility must be, in a satisfactory black, nicely balanced between the two extremes of clumping and complete isolation of the particles; this shows up in the electron microscope picture, which should show chain-like aggregations when the specimens are prepared from tertiary butyl alcohol suspensions.

3. A suitable black should have a particle size not more than 38 millimicrons; this may be directly measured on the electron micrograph.

The results of this investigation may be visualized in this manner. The dispersibility enables a small amount of black to mechanically form throughout the MnO_2 a web-like lattice of interconnecting chains, yet these particles must be conductive themselves (graphitized), and they must be small enough so that excessive amounts of black are not required. Other factors, such as water adsorption, surface films, interactions between MnO_2 and carbon, etc., are ignored in this visualization. Yet this method is a very rapid one, and results seem valid. An obvious objection could be raised to the use of x-rays instead of direct conductivity tests to measure partial graphitization; results of conductivity tests, however, just do not correlate with the observed effectiveness of a black in a battery, while the x-ray results do.

This study has shown a very unique and effective correlation of research tools. It now guides the production of carbon blacks for dry cells, and shows the necessary requirements for an effective one. It provides further evidence for the validity of the conductive-chain theory of carbon black conductivity in the mix.

QUENCHING OIL STUDIES

(Ind. Eng. Chem., Anal Ed. *16* 740-745 (1944).) Aluminum alloy motor castings quenched in oil in a 5000 gallon tank have exhibited increased internal strain with repeated use of the quenching oil. The quenching was from a temperature of 480°C., and apparently the oil became partially oxidized by use. A study for the evaluation of the deterioration in the oil was made by Clark and Kaye at the University of Illinois. A spectrophotelometer was the basis of the study. Relative transmission values were measured for the original oil and for oils heated in the laboratory. From these data information concerning the mechanism of the changes in the oil was obtained. Metals, such as aluminum, were found to increase the initial rate of oxidation, and various antioxidant additives were evaluated. Oil samples withdrawn from the quenching tank in the foundry revealed that the laboratory tests were truly analagous to the actual processes effective in the tank. Thus a good method for the evaluation of the oils was developed using the spectrophotelometer.

The electron microscope has had much to do with this method, as it has revealed much of the actual mechanism behind the observed phenomena. Micrographs of the oil have shown that definite solid particles are produced in the oil as it becomes partially oxidized. These particles, which are as big as 0.5 micron, are probably low molecular weight polymers. Now, the spectrophotometric observations must be based upon light absorption, fluorescence and/or scattering. The presence of these particles, as proved by the electron microscope, indicates that scattering must be a major factor. This means that the relative transmission curves must actually be a measurement of the amount of particles in the oil. The presence of these particles could conceivably have a large influence on the heat conduction of the oil, which is likely a major factor in determining the residual strain left in the aluminum casting after quenching. Further tests have shown that when the particles are removed by filtration of the oil, as indicated by electron micrographs, the residual strain in the castings is less than in those quenched before filtration.

Thus the electron microscope has revealed some of the mechanism behind a spectrophotometric evaluation of quenching oils and has aided in the development of a better oil.

AGE-HARDENING OF LIGHT METALS AND ALLOYS

("Electron Micro radiographs of Light Metals and Alloys." Thesis, University of Illinois, R. B. Fischer) (1944). Among the most prominent of the light metals and alloys finding great use in present day manufacture, especially in the aircraft industry is duralumin. Duralumin is an exceedingly hard aluminum base alloy containing usually four percent copper, and lesser amounts of magnesium, manganese, iron, and silicon. Dr. Wilm discovered thirty years ago that some aluminum alloys exhibited what is now known as age-hardening properties. A block of such an alloy, when heated, quenched, and allowed to stand at ordinary

room temperatures, increased in hardness, as shown by any standard hardness testing apparatus, for a period of hours or even days from the time of quenching. Many different alloys and heat treatments were tried out soon after Wilm's first discovery, and duralumin is a specific result of these investigations. No absolute proof of the cause nor the mechanism of this change was found at that time, and many methods of research were used in an attempt to find that cause and mechanism. For twenty-five years the usually accepted theory has been that proposed by Merica.

According to this proposal, the copper and other minor constituents are largely placed into solid solution in the aluminum upon heating due to their greater solubility at high than at low temperatures; upon quenching, a supersaturated solution is produced; upon standing, particles, chiefly of $CuAl_2$, gradually precipitate from the solid solution. These precipitated particles serve as "keys" between the grains of the metal, thus making it harder than the pure metal would be. There should be an optimum particle size at which a given amount of copper, in the form of $CuAl_2$, would produce maximum hardness. This optimum particle size was calculated to be less than the upper limit of resolution of optical microscopes; so it was not alarming to find that optical metallurgical microscopes revealed no precipitated $CuAl_2$, except in cases of relatively soft aluminum-copper alloys in which the precipitated particles were much larger than the optimum particle size referred to above.

Much work has been done on this problem of age hardening, and considerable data have been amassed along various lines: x-ray diffraction, hardness measurement, tensile strength, electrical conductivity, volume change, etc., all of which have indicated that the age hardening of duralumin is, to say the least, a very complicated and obscure process.

It was natural to investigate this problem further with the advent of the electron microscope in an effort to detect some actual microscopic evidence of the processes occurring during the hardening or aging period. Usual methods of metallographic study involving the use of plastic replicas of the metal surface, have not proved to be feasible in this particular study, so a new technique was developed, in which very thin specimens of the alloy were prepared and subjected to the entire heat treatment and aging procedure. Interpretation of the results is difficult, although some definite appearance of a precipitation during aging has been established. Thus the electron microscope has at last provided some direct evidence that the age hardening of duralumin is a precipitation process.

These three examples of recent applications of the electron microscope have illustrated several things: The instrument is of primary usefulness when used in conjunction with other instruments and methods of research; it is of great use in practical industrial problems; it is of great use in problems of a more academic nature; it has exhibited great possibilities as a tool in chemical research.

No mention has been made of the use of the electron microscope in other fields of endeavor. Probably the biological subjects proved its greatest usefulness. The reader is referred to the literature, as summarized in the bibliographies referred to above, for applications in this and still other fields.

GEOGRAPHY

GEOGRAPHIC PATTERNS OF ILLINOIS

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Within a state as uniform as Illinois, the delimitation of areas with sufficient homogeneity of cultural occupance and natural properties to possess unity, and yet with contrasts sharp enough to set them off from the general structure of the state is no small task. The map (fig. 1) presents basic patterns of interrelated areas intended to serve as the basis of further field investigation and the preparation of detailed geographic studies of selected portions of the state. It is not to be supposed that this is the only geographic system or that each area is a faultless delimitation; rather, it is an approach to the detailed geographic study of a state possessing the degree of similarities and differences found in Illinois.

BASIS OF AREAL DIFFERENTIATION

Illinois lies partly, and in a few instances, entirely within regions, provinces, or even realms of major proportion. Areal delimitation of such magnitude, which is shared with neighboring states, places a general stamp upon the state. The corn belt, the prairie, the humid interior climate, continental glaciation, the central dairy belt, the American industrial zone, and the like are elements in the regional personality of which Illinois is a part. Within the state, detail that gives quality to the local aspect is of major importance; it is the spark of life within the broader national or even world framework. Thus, the distribution of native vegetation, soil, glaciation, drainage, surface configuration, types of farming, settlements, density of population, transportation, and the proportion of total population engaged in agriculture, industry, mining, lumbering, and fishing are the chief items of local significance. No two items present identical state patterns, yet running through the innumerable combinations of cultural and natural environmental details are several threads of unity. In one area a natural feature seems to be the strong element of unity, in another a cultural condition, and in still another a dominant combination of cultural and natural elements. Thus the areas are delimited on the basis of the dominant or organizing features.

MAGNITUDES OF AREAS

The most conspicuous areal delimitation of the state is the presence of three major divisions arranged in a north-south manner and designated, chiefly by lack of better terms, as Northern, Central, and Southern divisions. Types of farming, settlement patterns, transportation patterns, and climatic differences, especially the length of the growing season, are the conditions upon which the divisions are based. A line from the Mississippi below the mouth of the Rock River to the great bend of the Illinois River to the Indiana state line separates the Northern and Central divisions,

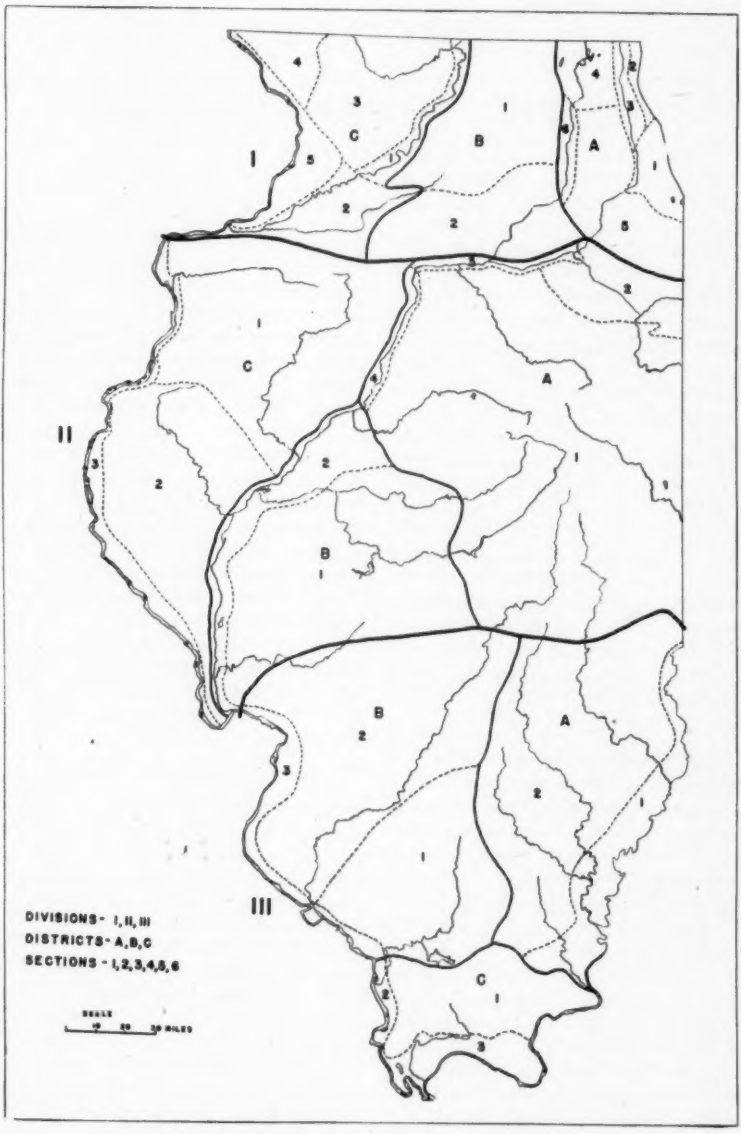

FIG. 1.—Geographic Patterns of Illinois.

whereas, a line from the Mississippi at the mouth of the Illinois to the Shelbyville moraine to the Indiana state boundary separates the Central and Southern divisions.

In a more detailed manner each division is separated into three districts and each district is reduced to several sections. In general the division falls into homogeneous districts in an east-west manner. The Northern division conveniently breaks into the Metropolitan district from the Fox River to Lake Michigan and the state boundary, the Western district from the Rock valley to the Mississippi, and the Moraine border district between the Fox and Rock valleys. Within each district are several sections each of which possess sufficient cultural and natural environmental agreement to warrant the delimitation of an area of that magnitude. Thus the Fox valley is one of the sections of the Metropolitan district and the Middle Rock valley and the JoDaviess hills are sections of the Western district.

The districts of the Central division are the Eastern, Southwestern, and Western. The Eastern district is enclosed by the state boundary, the Illinois River, and the Shelbyville moraine. The Southwestern district lies between the Shelbyville moraine and the Illinois valley, whereas the Western is the triangle between the Illinois and Mississippi valleys. Districts such as the Grand prairie, the Kankakee lowland, the upper Illinois and middle Illinois valleys constitute the Eastern division. The Sangamon plain, the lower Illinois valley, the Galesburg prairie, and the Mississippi border are in the Southwestern and Western districts.

In the Southern division the Eastern district extends from the Wabash River to the divide between the Kankakee and the Little Wabash drainage, whereas the Western district extends from that line to the Mississippi. The Southern district includes the tip of the state between the Ohio and the Mississippi from the northern edge of the Ozark hills southward.

The Southern coal section, the Metropolitan hinterland, the Wabash border, and the Ozark hills are some of the sections constituting the districts of the Southern division. The complete area structure in preliminary form is as follows:

GEOGRAPHIC PATTERNS OF ILLINOIS

I. Northern Division
   - A. Metropolitan district
     1. Chicago lake plain
     2. North shore and Border moraine section
     3. DesPlaines valley
     4. Lake section
     5. Valparaiso moraine section
     6. Fox valley
   - B. Moraine border district
     1. Northern section (Rock tributary)
     2. Southern section (Illinois tributary)
   - C. Western District
     1. Middle Rock valley
     2. Green-Rock lowland
     3. Northwestern upland
     4. JoDaviess hills
     5. Mississippi border (northern segment)

II. Central division
   - A. Eastern district
     1. Grand prairie
     2. Kankakee lowland
     3. Upper Illinois valley
     4. Middle Illinois valley
   - B. Southwestern district
     1. Sangamon plain
     2. Lower Illinois valley
   - C. Western district
     1. Galesburg prairie section
     2. Upland forest section

3. Mississippi border (central segment)

III. Southern division
   A. Eastern district
      1. Wabash border
      2. Embarras—Little Wabash section
   B. Western district
      1. Southern coal section
      2. Metropolitan hinterland
      3. Mississippi border (upper southern segment)
   C. Southern district
      1. Ozark hills
      2. Mississippi border (lower southern segment)
      3. Ohio border

GEOLOGY

MINIATURE FOSSIL CONCRETIONS OF MAZON CREEK

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The Mazon Creek area in northeastern Illinois has long been recognized as one of the world's most famous localities for Pennsylvanian flora. Here the superb fossil impressions are preserved in ironstone concretions, or nodules, of exceptional interest.

Since isolated plant fragments have here acted as nuclei around which the concretions have formed the concretions roughly approximate the sizes and shapes of the enclosed fossils. The smallest nodules are round or oval in shape and are about the size of a marble or walnut. The larger ones are usually elliptical, being several times longer than wide, with maximum lengths of twenty inches or more and widths up to six inches. The larger ones generally contain complete plant parts, such as fern pinnae, leafy tree twigs, or sections of trunk. The smaller ones contain single or ultimate units of plant parts, such as pinnules, small pinnae from terminal portions of fronds, buds, seeds, or immature organs. Since the larger concretions contain the larger, more complete fossils, more attention has been given to them in studies of the fossil plants. The tiny ones, however, are equally interesting because the fossils preserved in them are similar in quality to the larger ones, Also, some kinds of plant parts, such as seeds and pinnules, by their very nature of being small in size, may be found abundantly in the smaller nodules, and be rare in those of large or average size.

In order to evaluate the variety of flora represented in the small, or so-called miniature, concretions, a study was made of an assemblage totalling 440 miniatures. For the purpose of this study, only those nodules measuring less than one and three-quarters inches in greatest diameter were considered. For the most part, however, their dimensions were considerably smaller. These were collected at various times over a period of several years from the strip-mining shale heaps of the Northern Illinois Coal Corporation's workings in Will and Grundy counties. The genera of plant fragments found in them are summarized as follows:

Fern foliage; pinnules and small pinna:	
Neuropteris	168
Asterotheca	80
Ptychocarpus	28
Alethopteris	18
Diplothmema	7
Sphenopteris	5
Odontopteris	1
Total fern foliage	307
Calamites rushes:	
Calamites stems	3
Annularia leaflets	74
Asterophyllites leaflets	4
Paleostachya cone	1
Macrostachya cone	1
Total Calamites	83
Lycopodiales tree fragments:	
Lycopodites leafy stems	3
Lepidostrobophyllum bracts	21
Lepidophyllum leaves	4
Total Lycopodiales	28

Gymnospermous seeds:	
Holcospermum	9
Cordaicarpus	8
Total seeds	17
Sphenophyllales herb:	
Sphenophyllum leaflets	2
Sphenophyllum stems	3
Total Sphenophyllales	5
Total number of specimens	440

From the foregoing figures, it can be seen that nearly 75 percent of the miniature concretions contain fern leaf foliage. Since such foliage always predominates in any representative collection of coal age flora, the Carboniferous has often been called the Age of Ferns. However, among the miniature concretions, this predominance is even greater than the average. This can be accounted for by the very nature of the foliage itself. Because fern fronds are subdivided numerous times into smaller units, called pinnae and pinnules, these readily fall apart after death of the plant and tend to become buried and preserved as tiny, isolated units. Hence they would give rise to unusual numbers of the tiny concretions. Next in order of abundance among the fossil miniatures are the *Annularia* leaflets. These grew in whorls around the *Calamites* stems; hence, in falling apart, they too provided the nuclei for great numbers of small nodules.

Rarest among these concretions, as a group, are those containing the little leaflets of *Sphenophyllum*. Their rarity, probably, is in accordance with the general uncommonness of the genus itself, rather than because of the nature of the plant fragments. It is interesting, too, to note that among the various genera of fern foliage, *Neuropteris* is extremely abundant, and *Sphenopteris* very rare; whereas both are quite common among the larger concretions. This may be explained by the fact that the pinnules of *Neuropteris* were attached to the rachis by a single point, and so would readily fall apart after death. Those of *Sphenopteris*, however, were attached by much broader bases, and would not separate from the stems as easily. Hence, the ultimate units of *Neuropteris* would provide abundant miniature concretions, but the larger units of *Sphenopteris* would preclude abundant formation of miniatures.

PHYSICS

TIME LOSS AT STARTING FOR A SPRINTER

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Much to the dismay of every track coach in this country, there seems to be some lag at the start of every race. For the shorter distances, up to 100 yards, any lag is of extreme importance because a reduction of 1/10 of a second in the runner's time is an achievement.

That there is such a lag, and the extent of this time loss, is shown quite clearly by the graph obtained in the following manner. If the world record times for the dashes of various lengths are plotted against the distance run, the resulting chart will be a straight line up to the point corresponding to 100 yards (Fig. 1). After this distance, the runner ceases to run uniformly, and the line begins to curve toward the time axis. The points corresponding to the 40, 50, 55, 90, and 100 yards all fall upon the same line. The records for the 60 and 70 yard runs are poor, but, the 60 yard record was made in rubber soled shoes on a cinder track, and the 70 yard dash was made on grass.[1] Because the points fall upon a straight line, the slope, and therefore the velocity, ds/dt, is a constant. This means that for short distances, a runner making a record holds a maximum speed, and this instantaneous velocity, ds/dt, is the fastest speed obtainable in the light of the records which are available. The value of this velocity calculated from the graph, is approximately 37.5 feet per second.

If the line graph is extended from the point corresponding to 35 yards to that representing zero distance, the line does not pass through the origin, but crosses the time axis at a point equal to 1.2 seconds. This may be interpreted as meaning that the runner who is heading for a world's record, would breast the tape at exactly the same instant as a "perfect" runner who would stand at the starting line for 1.2 seconds, and then instantaneously would begin to run at the maximum velocity.

In order to determine the curve with which the runner accelerates, some method must be devised to record both time and distance intervals. It is this curve which will tend to bend the line on the graph down to the origin. The necessary data for the experiment were obtained at the outdoor track at the college in the following manner. Seven pairs of stakes were driven in the ground, seven on each side of the track. The first pair marked the starting line, and the others marked two yard intervals, all the way out to twelve yards. To one of the stakes at the starting line was attached a device whereby the expanding gases of the starting gun would cause an electrical contact. On the other six stakes upon the same side of the field were attached small switches which would be closed by a pull upon the thread with which they were attached to the other side of the track. With this arrangement of strings and switches, a runner would start

[1] These records were obtained from Cromwells-Championship Field and Track.

running, and close electrical contacts every six feet along the track. All six switches and the starting arrangement were connected in parallel in such a way that the closing of any one of the switches would cause a mark upon a moving tape in a Gaertner tape recorder nearby. A small synchronous motor was also attached to the recorder in a manner so as to transmit impulses to the traveling ribbon every 1/5 of a second. As a runner starts and speeds down the track, for the first twelve yards, small marks are recorded on the tape at the time the gun goes off, and every time a string is broken. Parallel with this series of marks, but removed a few millimeters are recorded the 1/5 second impulses of the synchronous motor. The ribbon may then be removed, and the distances measured and calculated. When the average velocity between two stakes is plotted against the time required, there results a curve which starts out quite steeply, climbs steadily, and then tapers off to a line parallel with the x-axis corresponding to zero slope and constant veloc-

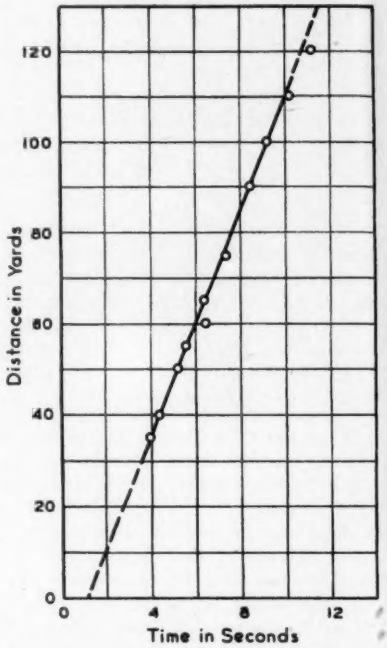

FIG. 1.—World record times for various races plotted against corresponding distances.

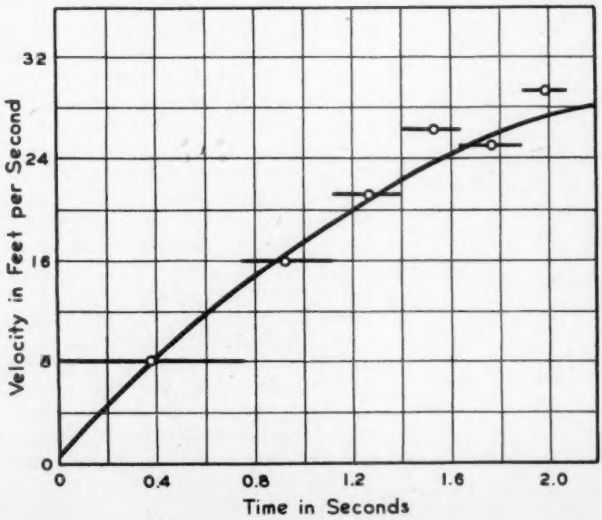

FIG. 2.—Velocity time curve from the average velocities during corresponding time intervals.

ity (Fig. 2). This straight line may correspond to any velocity and probably will depend upon the man who is running. The constant velocity line will, however, never be equivalent to or be more than 37.5 feet per second, unless the runner ties or beats the world records up to 100 yards. If he could keep up the rate, he would smash every record over that distance. After 100 yards, however, other factors enter in and the runner must slow down. Some work has been done by others on the track records for distances of 200 yards and more.[2] In this case a whole new set of laws come into use. No longer does the start have the importance that it does for the short distances, and also the body, at the end of a long race is almost completely exhausted, while this is not true for dash and sprint races.

It is fascinating indeed to apply the laws of physics to a man who is straining every muscle to better himself in the field of sports. Whole books could be written on the subject; the force exerted by the legs, the horizontal and vertical component of this force, the difference in time caused by different running surfaces, and the limitations due to inertia might well be used as chapter headings in such a volume. In conclusion, acknowledgement is made to Dr. Martin for his help and suggestions. Also to members of the Physical Education Department who helped so freely, many thanks are given.

[2] Dr. Alfred W. Francis, "Running Records," *Science Magazine*, October 8, 1943, pp. 315-316.

THEORETICAL PHYSICS AND PIONEERING RESEARCH IN ILLINOIS MINERALS

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The title of this paper has been deliberately worded to emphasize the cardinal fact that higher physics is universally based on theory and that true research possesses the essential pioneering quality.

The paper is divided into two independent parts; the first half concerns the stuff physics research is made of and the second half illustrates its application to Illinois mineral industries.

UNDERSTANDING OF RESEARCH

According to Westbrook Steele, Executive Director of Institute of Paper Technology, research accomplishments attendant on the first World War led to a condition that might be classified as research worship rather than understanding of research.

Obviously a clear understanding of the prime ingredients of physics research is of higher import than the blind worship of research. The first step to such understanding is a clear delineation of the modus operandi of physics research.

Definition of physics.—It has been stated that what we call physics comprises that group of natural sciences which base their concepts on measurement and whose concepts and propositions lend themselves to mathematical formulation. This realm is accordingly defined as that part of the sum total of our knowledge which is capable of being expressed in mathematical terms. With the progress of science, the realm of physics has so expanded that it seems to be limited only by the limitations of the method itself. The larger part of physical research is devoted to the development of the various branches of physics, in each of which the theoretical understanding of more or less restricted fields of experience and in each of which the laws and concepts remain as closely as possible related to experience. It is this department of science, with its ever-growing specialization, which has revolutionized practical life and given birth to the possibility that man at last be freed from the burden of physical toil.

It is apparent that by this definition physics must be regarded as including such component specialized fields as mechanics, electrodynamics, thermodynamics, hydrodynamics, optics, electronics, constitution of matter, chemical reactions, petrography, and those portions of natural and social sciences possible of mathematical formulation with resultant experimental verification.

Furthermore, secondary physics deals mostly with statics whereas advanced physics is concerned exclusively with dynamics or flow of energy.

Origin of research.—Bacon is the father of what is known as the scientific method which is the basis of physics research. In his *Novum Organum*, perusal of which is recommended to all who aspire to research as a career, Bacon divides research into three progressive steps: induction, experimentation, and deduction. The tools of induction and deduction are mathematics whereas the tools of experimentation

are instruments. Since research consists of a composite of these three steps, the absence of any one of the steps disqualifies the work as physics research. Experimentation, unattended by both induction and deduction, resolves itself into routine testing and this is not research. Conversely experimental research is an incongruity unless it is associated with theoretical research.

Physics research.—Due to the urgency of speedy accomplishment, usually it becomes expedient for the research physicist to utilize either recording instruments or assistants to carry out the experimentation. Doubtless Gibbs was the most distinguished of all American research physicists, relying almost exclusively on the experimental findings of others. Likewise, as F. W.. Moulton has noted, Archimedes, Aristotle, Galileo, Newton, Lyell, Darwin, Dalton, and Mendeleef were not simply, or even primarily, observers; their active and penetrating minds grasped the observational and experimental evidence relative to the subject in which they were interested and organized it into coherent scientific thought. Synthesis or deduction is the final and culminating step in the scientific process, but may not always be the product of the same individual who performs the earlier steps.

The present war is based on physics research. Conant has aptly designated it as the "physicist's war." H. B. Ward, Past Permanent Secretary of the A. A. A. S., expresses the belief that K. T. Compton, as the war organizer of American physics, has contributed more than any one else to our forthcoming victory.

The mathematical tool. — Mathematics is the hand-maiden of physics research. And inasmuch as physics deals with the flow of energy, the working knowledge of partial differential equations is the minimum requirement in physics research.

To E. B. Paine, Emeritus Head of the Electrical Engineering Department of the University of Illinois, has been delegated the task of selection of war-time girl-cadets by several large industries. He finds that any cadet who has mastered partial differential equations during her apprenticeship becomes useful as a research aide, regardless of her lack of knowledge along all other lines.

There exists one unfailing yardstick for minimal ability in research in the aforementioned physics sciences. This yardstick is daily usage of partial differential equations. Those who do not possess this ability are superficial in research in the physical sciences.

Inherent research qualities. — In addition to qualities which may be attained through training, a research man must be born with certain inherent qualities. These include character, curiosity, and sense of humor.

Character may be defined as honesty. A. W. Hull states that in research the greatest scientific sin is wishful thinking. Rationalization is diametrically opposed to the spirit of research.

W. R. Whitney holds the opinion that curiosity is the most important research quality. Alan Gregg, of the Rockefeller Foundation, states that if there be some measure of truth in the observation that children seek the unknown but adults fear it, then research is the fountain of eternal youth, for research, whose purpose is to meet the unknown, provides our minds with the perennial freshness and delighted curiosity of youth.

W. T. Chevalier believes that the sense of humor is the most important

quality in research. The reason is that humor is based on incongruity or lack of proportion. In order to appreciate lack of proportion one must possess a keen insight into proportion, which is most essential to a research man. Eddington created the imaginary Scottish professor of Geloeology, who thoroughly understood the rules of this hypothetical science of humor, and could infallibly classify any kind of joke—without ever having seen it.

In addition to the above three minimal, inborn research qualities, high success in research depends on brilliancy of imagination.

The fruits of research.—The accomplishments of research are invention. Invention may be defined as something new. Also invention includes novelty and originality in (a) processes, (b) equipment for carrying out the processes, and (c) products made by means of such processes and equipment. Often, and perhaps usually, inventions are not immediately utilized, but eventually use is found for most, if not all, inventions. The basic inventions having to do with production of electricity antedated its industrial use by two generations. In this war, perhaps radar is the most important of all weapons; again with a generation between its invention and its use.

RESEARCH IN ILLINOIS MINERALS

Having considered briefly the nature of physics research, attention now will be focused on its applications to Illinois minerals. Such applications may be illustrated by citing a few examples. Since the research in Illinois minerals is most extensive, the limits of time permit only the review of selected illustrations, which will be confined to physics research carried out by the Illinois Geological Survey.

The topics for discussion comprise theoretical research in fields as follows: heat of combustion of coal calculated from energy liberated due to interdisplacement of valence electrons during combustion; air classification of pulverized material; plastic flow of coal; electric condenser demulsification of oil; smoke index as a quantitative measurement of the smoke content of coal; and effects of partial prevolatilization of coal and concentration of fusain on the smoke content of resultant briquets.

Heat of combustion of coal.—The bituminous matter of coal consists of aromatic hydrocarbons with molecular arrangement approaching that known for corresponding pure hydrocarbons. By means of quantum mechanics, the orbits of valency electrons before and after combustion of a particular type of hydrocarbon are known and the energy liberated due to interdisplacement of valency electrons during combustion may be calculated. The resultant calorific formula for bituminous coals is

$$q = 252\ [H + C/3 - O/12.5] \quad (1)$$

where q is the heat of combustion in cal. per gr. and H, C, O are percentages by weight of hydrogen, carbon, and oxygen, respectively.

This formula holds throughout the range of rank of coal from peat up to anthracite. In the anthracitization or carbonization of coal, the carbon changes from a hydrocarbon to a free carbon (carbon-carbon bond) and therefore the constant 252 changes to 240.

The oxygen in coal reduces the effective hydrogen in coal, which may be considered numerically as the total percentage hydrogen less 0.08 percentage oxygen. From this follows the concept of a hypothetical pure CH coal, composed only of car-

bon and effective hydrogen. The composition of this CH coal for all ranks of coal from peat up to anthracite is remarkably constant, consisting of 5.0 ± 0.5 hydrogen and 95.0 ± 0.5 carbon, with a calorific value of 9250 ± 100 cal. per gr., this constancy being within experimental accuracy.

From this CH coal concept and from the constancy of composition, it follows that the coalification process, up to the anthracite stage, was carried out under conditions of geologic equilibria of energy level.

Air classification. — Classification consists of separating a granular material into two (or more) screen sizes. Also a mixture of two materials possessing different densities, but the same screen size may be classified into its two components. Air classification is carried out under conditions of turbulent flow. The theory of air classification may be developed as follows:

The downward gravitational force on a spherical particle is

$$f = \frac{\Pi\, d^3\, D_p\, g}{6} \qquad (2)$$

where d, D_p are the diameter and the density of the particle, respectively.

Newton has shown that the upward force is

$$F = \frac{\Pi\, d^2\, D_m\, V^2\, C_d}{8} \qquad (3)$$

where D_m, V, C_d are the density, the velocity and the drag coefficient of the air.

The critical velocity of the air at which the particle remains suspended, obtained from solving the above equations, is

$$V_c = \left[\qquad\right]^{1/2} \frac{4\, D_p\, d\, g}{3\, D_m\, C_d} \qquad (4)$$

Zahn has discovered the relationship between the drag coefficient and Reynold's number, R, as follows:

$$C_d = 28/R^{0.85} + 0.48 \qquad (5)$$

Also Reynolds has shown that

$$R = \frac{D_m\, d\, V_c}{\nu} \qquad (6)$$

where ν is the viscosity of the air.

Since the drag coefficient changes with velocity, direct calculation of the critical velocity is difficult, if not impossible. However, a graphical solution may be readily obtained. From equations 4 and 6

and
$$V_c = \left[\frac{4\, D_p\, g\, \nu\, R}{3\, (D_m)^2\, C_d}\right]^{1/3} \qquad (7)$$

$$d = \left[\frac{3\, \nu^2\, R^2\, C_d}{4\, D_p\, g\, D_m}\right]^{1/3} \qquad (8)$$

Then various values of Reynolds' number are taken one at a time, the corresponding drag coefficient is calculated from equation 5, and a graph is plotted for critical velocity versus particle diameter.

The resultant graph approximates a straight line, the equation of which is

$$V_c = A\, d - B \qquad (9)$$

where A is the slope of the line and B is the intercept. For clay particles, density 1.8, the numerical values of A and B are 6687 and 22.5, respectively.

Air carrying capacity A_c may be defined as the weight (gr) of material carried upward through unit cross sectional area (cm^2) per unit time (sec.).

Experimental results show a straight line relationship between air carrying capacity and the velocity less critical velocity. The equation of which is

$$A_c = K\, (V - V_c) \qquad (9a)$$

where K is the concentration of material in the rising stream in units of gr. per cc. For clay the constant K, has a numerical value of 0.016.

In Illinois, air classification is being used extensively in coal dedusting plants, in sizing of silica and other pulverized products. Also it is a potential method for dry removal of pyrite from ground clay.

Plastic flow of coal.—In conjunction with a project on briquetting Illinois coals without a binder, a study has been made on the plastic properties of bituminous coal under various pressures, temperatures, and periods of compressions. The plastic properties are measured in terms of changes in density of the briquet during the period of compression. Thus in mathematical analysis, the independent variables are pressure, temperature, and time.

For a given temperature and time, experimental results show a straight-line relationship between the log density and log pressure. For various temperatures there is a family of straight lines meeting at a critical point, representing a critical density, which is the pore-free density of the coal, and a critical pressure,which is the pressure necessary to produce the critical density. The equation of this family of straight lines is

$$D = D_c [P / P_c]^m \qquad (10)$$

where D and D_c are the resultant density and critical density, respectively, P and P_c are the applied pressure and critical pressure respectively, and the exponent m is the slope of each line of the family, with a value dependent on temperature and time.

For a given time, experimental results show a straight line relationship between the exponent m and the fourth power of the absolute temperature. The equation of this line is

$$m = F - n\,T^4 \qquad (11)$$

where F is the Y-intercept and n is the slope of the line.

For various periods of time, experimental results show a straight-line relationship between the slope n and the logarithm of the time. The equation of this line is

$$n = G + p \log t \qquad (12)$$

where G is the Y-intercept and p is the slope of the line.

Combining equations 10, 11 and 12

$$D = D_c \left[P/P_c \right]^{F - T^4 [G + p \log t]} \qquad (13)$$

The constants in this equation possess values characteristic of various types of bituminous coals. The values for an Illinois coal in the Belleville district is D_c, 1.32; P_c, 25,100 pounds per square inch; F, 0.175; G, 0.0; and P, 2.21×10^{-13}. Therefore

$$D = 1.32 \left[P/25100 \right]^{0.175 - 2.21 \times 10^{-13} T^4 \log t} \qquad (14)$$

The critical density of various bituminous coals is reasonably constant, with small variations due to variations in ash content. The critical pressure increases with rank of coal with values of about 45,000 and 55,000 pounds per sq. in. for Franklin County, Illinois, and West Virginia Pocahontas, respectively.

Inspection of equation 14 shows that in the formation of a dense briquet, the pressure and temperature are dominant factors, the period of compression being relatively unimportant.

Electric condenser demulsification of oil.—In oil fields nearing depletion, the crude oil usually contains a water emulsion which is difficult to break down. The toughness of the emulsion is due to interfacial electric charges. The conventional

treatment has consisted of passing high voltage alternating current through the oil. Many ingenious electrical and mechanical methods have been used in an attempt to prevent short circuits with resultant explosion hazards.

A working knowledge of electric potential flux indicates that it is the electric field (and not the electric current) that breaks down the emulsion. Two types of electric condenser dehydrators have been designed. In one type the emulsified oil flows between two parallel sheets of glass, spaced about 1 cm. apart. The outer surface of each sheet is covered by foil. The two sheets of foil form the opposite leaves of a condenser which is activated by a spark coil. The second type consists of a one-inch iron pipe, with an axial glass covered electrode insulated from the pipe. The pipe serves as the grounded side of a condenser and the electrode as the opposite side of a condenser, also being activated by a spark coil.

Smoke index method.—Prior to development of the smoke index method, there was no accurate satisfactory method for quantitative determination of smoke.

The smoke index method consists of burning a weighed quantity of coal under standard conditions of air flow and temperature. A constant intensity light beam cuts across the smoke path. A photo electric cell measures the percentage of light absorbed by the smoke, by means of a Micromax recorder. The smoke index numerically is the product of the percentage light absorbed and the time of smoke liberation per pound of coal.

The smoke index tests normally show less than 50 percent light absorption. However, if tests are made in excess of this density of smoke, then correction may be desirable due to Lambert's law, which is

$$I = I_o e^{-kx} \qquad (15)$$

where I and I_o are the transmitted and original light intensitites, respectively, and x is the density of smoke, and k is a proportionality constant.

Up to 60 percent light absorption there is almost a straight-line relationship between percent light transmission and density of smoke.

Factors affecting smoke index.—In preheating, prior to briquetting, various percentages of volatile matter may be liberated from the coal by partial prevolatilization. If the percentage volatile matter in the resultant briquets is plotted versus the smoke index, a straight-line relationship becomes evident, the smoke index, dropping to zero when one third of the volatile matter is removed.

Illinois coals are banded, one of the bands, often a parting plane, being composed of fusain which is a pulverant natural charcoal. The fusain tends to concentrate in deduster dust, the percentage of fusain depending on the fineness of the dust. If the percentage of fusain in the resultant briquet is plotted versus the smoke index, a straight-line relationship becomes evident, the briquet being commercially smokeless with about 15 percent fusain.

FUTURE OF PHYSICS RESEARCH

Physics research is cumulative, similar to a snow ball. Pioneering research, with resultant solution of any physics problem, opens up a homestead in a new territory with multiple research fields to be explored and conquered.

PSYCHOLOGY AND EDUCATION

CLINICAL PREPARATION OF TEACHERS FOR THEIR DIAGNOSTIC ROLE IN THE CLASSROOM

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One of the vital, as well as interesting trends in teacher education during the past decade is to be noted in the increased emphasis upon the preparation of teachers for what might be termed a diagnostic function.

In the full sense of this term, no unspecialized person is a diagnostician, and there is no attempt here to imply that a teacher can adequately perform the duties that properly lie within the province of the medically trained person, the psychologist, or the school nurse.

However, it is of interest to note that during the past fifteen years nearly a thousand teacher-preparing institutions have established bureaus of child guidance, while others have set up various other programs for the preparation of teachers in the specialized performance of functions that serve a diagnostic purpose.

It is the purpose of this paper to outline the major skills that the newer type of training is giving to teachers who formerly were taught merely the methods of subject-matter instruction.

In my own institution of Southern Illinois Normal University we have a *Bureau of Child Guidance* under the directorship of Dr. Wellington A. Thalman. If, in the present paper, I devote most of my attention to the kind of work that we are performing, it is because I believe that our own program is somewhat typical in its aims and organization.

Two major purposes are recognized. The first is that of preparing teachers for the field. The second is that of service to cases which appear before us. I propose merely to discuss the former purpose, that of preparing teachers for improved guidance of their children.

To begin with, both graduate and undergraduate courses have been established in the nature of research seminars. The prospective teacher is required to have a relatively heavy background of prerequisite courses in psychology, education, sociology, psychometric measurements, health education, and sociology.

In the seminar courses, each class member is required to select a patient. Usually the patient is one which has been referred to the Bureau by a social agency, a court, or a school administrator. The child is usually one who has failed to perform at a satisfactory level in his school work. Usually there are complicating factors of delinquency and personality maladjustment.

After the selection has been approved by the director, the teacher is guided in the building of a case history, the giving of tests, and the study of guidance and diagnostic procedures. The teacher must bring the patient to the Bureau, must see that a competent physician makes a

complete medical examination, must visit the home, and must gather data on the patient's past school record, medical history, family background, and present symptoms of maladjustment.

We feel that it is wise for the teacher to accompany an experienced social worker in the first visit to the patient's home. If rapport is attained on this first visit, the teacher may then make some of the subsequent visits alone.

A large part of the teacher's training deals with techniques of holding conferences with the patient and parents, evaluating the patient's performance in the light of his special abilities and disabilities, and administering tests for the measurement of achievement, aptitudes, and intelligence. If a case appears to be one in which there is danger that damage might be done by an inexperienced person, it is not left in the hands of this teacher but is handled by the professional members of the staff.

It should be mentioned here that the staff which guides the learning teacher includes one or two physicians, one or two psychologists, a specialist in reading problems, a nurse, a social worker, one or two specialists in education and teacher training, and, for occasional help with some cases, a psychiatrist or some other specialist who may be brought in for study and staffing of particular cases.

The aim of the entire program of training is capable of being broken down into three main areas, as follows:

First, the development of a "clinical" approach in which the teacher will see child conduct not as an entity upon which she is to pass judgment, but as a symptom for which she is to seek the underlying causes;

Second, the development of skill in evaluating a child's performance and behavior, not in terms of standard performance norms alone, but in terms of the child's own previous performance; and

Third, the development of skill in making at least preliminary diagnosis of performance and behavior to find abnormalities, to suggest possible causes, and to seek professional service in final diagnosis and therapy.

The teacher not only follows the case through a full twelve-week period of observation and study, but participates in the final professional staffings in which the individual case is considered by the physicians, psychologists, and other staff members who have been working with the patient.

A somewhat incidental but interesting aspect of the teacher's growth through this kind of training is frequently noted in cases where a parent, teacher, or other person has mishandled a child's problem. Our own record files are full of such cases to provide the learning teacher with evidence. A few illustrations from these files will show what is meant here.

One was the case of a boy whose teacher was sure that he suffered from some kind of "degeneration" of his brain. The boy was in the fifth grade of a public school and was reported to be the "bully of the school grounds." His teacher said that he could not learn and that he was at the foot of his class. He could not read. She was confident that he was undergoing a deteriorating process mentally; for he had been known as a "bright" pupil in the first grade and had led his class. Various sorts of punishment had been administered and he had been retained in his grade once. None of the teachers liked him. His room

teacher admitted that she couldn't stand the thought of having him another year, for he had completely antagonized her.

The boy was taken as a case by one of the students in the guidance seminar. This student saw every conceivable test used; saw the child's responses in psychological interviews; saw the complete case history developed; and participated in the professional staffings. This student learned that the diagnostic approach is one which regards the patient's behavior impersonally, regardless how much it may be calculated to antagonize; and in the staffing this student remarked that, had she not had this kind of training experience, she would be inevitably inclined toward a complete loss of patience because of the child's unruly behavior. When it was discovered that, during the first months of the second grade, this boy had been absent from school because of illness, he was immediately given a simple test in phonics. He was found to be utterly without any concept of phonic analysis. In fact, and almost unbelievably, he was unaware that certain letters have specific sounds. He did not know, for example, that the letter "r" could not sound like "b" or "n" or "t." Such a complete lack of understanding is hard to explain; but investigation showed that, in his school, all phonics are taught during the first six weeks of the second grade, the very period during which he was absent. His native intelligence was high and he apparently had been able to memorize words and word forms in the first grade more readily than the other children. But after phonics had been taught them, the second-graders were left to their own initiative in identifying new words; and when the boy returned to school, he found himself unable to compete with his classmates, who now had acquired an essential skill of which he was ignorant.

By way of compensation for his loss of prestige in the recitations, the child apparently developed an aggressive tendency to play the part of the schoolground bully at the recess periods.

The recommendation of the staff included a strong appeal to his teachers that they should do nothing whatsoever about this boy's misbehavior. He should be individually tutored in phonics over a period of some months. These recommendations were carried out; and within six months the staff received a report from the fifth-grade teacher. She said—to quote her exact words—"Bobby is his old self again." And she stated that, not only was he now near the head of his class but that, to her great surprise, he had ceased to be the bully of the schoolgrounds and was making friends.

It seems needless to point out that a student who plans to teach children will get a point of view through clinical training that only such training can give; namely, that point of view which sees the child's behavior, not as an entity in itself, but as the symptom of underlying causes. Thus the teacher will learn that behavior is not to be judged or punished as such but is to be studied clinically with a view to determining the caustive factors.

A further case may be cited for the sake of contrast in the etiology of a somewhat similar problem. A fifth-grade boy was severely slapped about the face by his teacher for apparent refusal to cooperate in a timed drill test for which the teacher used a stop-watch. He again and again spoiled the experiment by delaying his beginning of the drill after the teacher's signal to start. The teacher complained also of the

boy's "impudent" way of looking at her when she gave the command for the class to begin the drill.

As in every case referred for guidance, the student member who had this boy as a patient, saw the complete building of a case record, participated in the consultation with parents and teachers, studied the medical report, and interviewed the patient himself. The medical history showed an unusual operation in early infancy, followed by infection and prolonged high fever. There was evidence to indicate that here might be a problem growing from purely physiological causes. Tests by a skilled physician and neurologist showed that the boy's case was one of post-encephalitic epileptiform behavior, explaining both his inability to react in normal time to a command as well as his partially paralyzed facial muscles which gave the "impudent look" that so angered his teacher. The result of the clinical staffing was that the boy was placed with a teacher who was given full information concerning his difficulty; and his adjustment to his school became very satisfactory.

In all cases of training, the teacher is given knowledge and experience in the proper place that vision and hearing tests play in diagnosis of children's disability diagnosis. The teacher, while not becoming an expert in the identification of disease symptoms, learns to at least note the presence of such symptoms through the regular health inspection and learns the proper procedure in isolating the child and securing medical aid.

Emphasis is placed upon the teacher's entire role in adjusting the curriculum to the child's aptitudes and special weaknesses, in studying his vocational interests and giving him guidance, in adjusting the school's requirements to the child's intelligence, and in attempting to see his total personality in the light of all causative factors.

In summary, it may be stressed as a fact of modern teacher education, that the past decade has seen a new movement in the scientific approach to the study of children. As a consequence, less emphasis is now placed upon subject matter as such and more emphasis is placed upon the individual child. At least eight hundred teacher-training institutions in America now have some kind of a guidance bureau functioning with this purpose in mind. Their advent has marked a turn in the history of teacher preparation. Under this new direction the trend of scientific thinking is away from punishment of the child and toward the development of a clinical approach to the study of his needs and his problems. This movement has supplied one of the chief characteristics of the newer program of teacher training. It is hoped that it will likewise supply one of the greatest modifications, or at least the beginning of modifications, in the methods by which teachers in our public schools make their professional work more scientific.

When it is recalled that, of the forty-five million children in the United States, only about two thirds are without handicaps or abnormalities of some kind, the need for such a scientific approach in education becomes apparent. Some two and a half million children of school age are handicapped in some way that necessitates facilities for their specialized education. Evidence indicates that not more than twelve percent of them are at present receiving such special education. These children include the blind, the near-blind, the crippled, the deaf and near-deaf, and the speech defectives but do not include the mentally de-

fective nor those children who, by reason of their superior talents or intelligence, need special adjustments in their curriculums. Six million children are improperly nourished, according to a rather recent report to the National Council of Childhood Education; and one million have weak or damaged hearts; half a million are mentally retarded; three million have impaired hearing; 300,000 are crippled; one million have defective speech; 200,000 are delinquents; and 382,000 are tubercular.

Training the teacher to recognize a child's problem is, therefore, no mere fad of the newer program. It is not mere publicity. It is not just an attempt to streamline education in terms of its superficial appearance. It is a new effort, long overdue, to make education more of a science and to equip it with the scientific materials for its job.

SOCIAL SCIENCE

SUGGESTIONS TOWARD A SOCIOLOGY OF ART

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Sociologists have made interesting studies of the hobo, the prostitute, the drug addict, and the criminal. They have made valuable contributions to the subjects of population, social change, the family, and other topics of sociological interest. They have done less than justice, however, with the subject of art from a sociological standpoint. Art is a significant social phenomenon, and deserves the careful attention of students of sociology. It is a product of the social thoughts and activities of men, and as such it is a vital reflection of the culture of a time and place. Art holds up a mirror, not to nature, but to human society. In contrast to the philosophical view of art which constructs metaphysical or epistemological theories around the subject, and to the psychological view which aims at a description of art in terms of sensation and perception, the sociology of art tries to discover the social and cultural roots of art.[1] It perceives the beauty in art, not as a metaphysical essence as philosophers do, nor as an experience that can be adequately measured in the laboratory as some psychologists would like to have us believe, but as a social process, a changing artifact conditioned by the prevailing institutions, mores, economic and technological developments, social attitudes, and the like. The central task of the sociology of art, therefore, is to discover the social and cultural conditions that are anterior to artistic achievement and responsible for the body of ideas from which artistic culture springs. From this point of view an artistic production must always be appraised in terms of the standards of the period in which it occurs, rather than by contemporary criteria.

Among the many problems in the sociology of art only a few will be briefly outlined.

1. Institutional aspects of art.— Institutional factors are all those formal and informal agencies in society which exert control over artistic productions, such as customs, tastes, public recognition, publications, art schools, museums, laws, etc.

An interesting problem is the role of professional criticism in art publications, the press, and the radio. Reviewers wield an influence, if not on the artist, then certainly upon the consumers of art. Music critics, acting as commentators at symphony broadcasts, can shape the musical tastes of their audiences. Symphony conductors in their capacity of selecting compositions, can elevate into famous artists composers of no great merit and discourage others of great promise.

The competitive nature of contemporary life has not left the artist untouched. To protect himself from predatory dealers and publishers the artist has been obliged to organize into associations and to secure copyrights for his creations. This in turn has given rise to legal experts who

defend their clients against their dealers. The freedom of the artist is thus effectively curtailed.

We do not yet know accurately the role of art schools, academies, and art galleries in artistic productions. The evidence suggests that they force potential artists into predetermined molds. Art galleries are in a position to select the works of those artists which are in conformity with their directors' ideas of what is good in art. It is well known that the productions of dissident artists are frequently rejected.

A problem of great concern, and one which is in need of careful research, is the role of foundations in art. To what extent is the will of a donor detrimental to the free growth of art? We do not know precisely; but it is sufficient to note that donors frequently limit the use of their gifts to conditions and circumstances which do not operate after their death.

2. Art and the economic system.—Art is conditioned by the economic circumstances under which it originated. Art and material culture are closely associated. The incentive for artistic creation is greatest among people whose time is not entirely consumed in securing a mere subsistence. In frontier America artistic creation was feeble in part because of the pioneer's preoccupation with material survival. American, like all art, is associated with the achievement of a relatively stable material economy.

Closely related to this problem is the relation between art and the class structure. If the general character of cultural life is affected, as it seems to be, by the material relations of production, then art is no less untouched by them. Accordingly, the dominant class that controls and manipulates these relations will also influence artistic productions. Art is, in short, influenced by class relations, especially by rich and powerful patrons.

3. Art, sectarianism, and the political process.—Philosophers, critics, and moralists have for centuries inveighed against the "immorality" of art and artists. Censorship of art has been an important influence upon art. Ecclesiastical control over art comes readily to mind. The agencies of suppression are also at work today. Mrs. Grundy has a sorry record for strangling the apirations of the artistic spirit. Literary art, especially, is often "made" or broken by the "guardians" of the moral order.

The relation between art and political institutions has long been recognized. It is only recent history, however, that has made us fully aware of the oppressive nature of political forces in relation to art. Communism and Naziism, each in its own way, has crushed all dissidence in art. The doctrinaire intolerance of the Soviet dictatorship and the ruthless suppression of all "non-Aryan" art in Germany cannot be here described; their effect on art in totalitarian countries is, however, well known.

4. Art and fame.—While it is probably true that, in the long run, an artistic production of exceptional merit tends to achieve public recognition, this recognition is dependent considerably on social circumstances. Artistic fame is social. The influence of the home, the school, and the special agencies of artistic training in the life of the artist must be taken into consideration. Frequently artistic fame depends upon influential intermediaries who can win favor or acclaim for a work of art through their prestige and au-

thority. Patrons, rich men, critics, and publishers are important factors in artistic recognition. A genius is, therefore, in great part a product of favorable social and cultural circumstances.

5. The personality of the artist. —Artists, like other people, differ among themselves. Despite this fact, however, they have characteristics which are more common to them than to non-artists. If we conceive of the artist as an "ideal type" or construct, then the real artist is a person who, while never merging with it, approximates it in various degrees. Again, while the personality of the artist, like that of anyone else, is laid down early in life, his role and status are significantly bound up with his "occupation." His life organization is conditioned by his being an artist "professionally."

The person who eventually becomes an artist was early confronted by deeply personal problems which were pressing for solution, such as unrequited longings, powerful unrealized ambitions, unusual desire to excel, problems of inner tensions and conflicts, and the like. The "temperament" of the artist is a composition of hyper-activity, verbal outbursts, violence to or withdrawal from the environment resulting from frustration of his powerful wishes. These traits are hardly conducive to individual repose and are more likely than not to produce an unhappy artist. This is particularly true of the modern, in contrast to the ancient and the mediaeval artist; for the modern artist must above all things be original. In a world of rapid change there is no settled or prescribed meaning of life. Each artist has to discover it through his own spiritual agony. The modern artist, in other words, has not only to delineate, but to invent his own meaning, of existence; it does not come to him ready made, like Christianity to the mediaeval artist. The need to inject order into the chaos of life taxes the imagination, intelligence, and creative powers of the artist to the limit. In this situation the artist cannot remain conventional or normal.

Among other topics in the sociology of art mention should be made of the following: the role of art-ideologies in art, the effect of scientific ideas on art, art as a means of social adjustment, the psychology of the creative experience, abnormality and the artist, psychoanalysis and art, the social nature of aesthetic appreciation, and art as social communication.

This brief statement of the nature of the sociology of art shows that it is an effort to look upon artistic productions objectively; to make art amenable to rational analysis by discovering its social and cultural origins. If art has meaning, as philosophers tell us it does, then that meaning can be in large measure ascertained by a knowledge of the culture that gave it birth. A work of art means, from this point of view, what the artist intends; and the artist intends largely what the cultural values direct. Art and culture are thus inseparable.

ZOOLOGY

ADDITIONAL NOTES ON PSEUDOSCORPIONS FROM ILLINOIS[1]

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During the past year, the writer has continued his studies of the pseudoscorpions of Illinois (*vid.* Hoff, 1944, 1945a). In the present paper, new records and notes, both descriptive and ecological, are given for five species. Unless otherwise indicated, records are based on collections of the Illinois State Natural History Survey.

Suborder HETEROSPHYRONIDA Chamberlin
Family Dithidae Chamberlin

Verrucaditha spinosa (Banks, 1893) Chamberlin, 1929
(Figs. 1-3)

RECORDS: *Verrucaditha spinosa* is not an abundant species in Illinois. The writer has found only six males, two females, and one tritonymph in seven collections. Four of these collections are from Adams County, one collection being made by Rev. Edbert Long, O. F. M., the others by the writer. The three remaining records are based on Illinois State Natural History Survey collections and include one collection from each of the following counties: Jackson Co., Jersey Co., and Madison Co. The species appears to have a wide range, extending from the Mississippi River Valley eastward to the coast, but individuals are nowhere abundant.

Verrucaditha spinosa occurs almost without exception in the debris and decaying wood of old stumps and logs, although one of the Survey collections was labeled "ground cover" and one of the Adams County collections was made from fallen needles under a red cedar tree. As a means of recognition of this species and separation from other Illinois pseudoscorpions, the following combination of characteristics is helpful: about 100 heavy spines on the carapace, anterior margin of carapace bilobed, the pair of tactile setae of the dorsum of the chelal hand removed from the proximal margin of the hand by about one-fourth of the hand length, and spines on coxae I and II.

MALE[2]: (Based on a study of five Illinois males cleared in beechwood creosote and mounted in Canada balsam.) Body length 1-1.25 mm.; carapace with five or six well-developed marginal setae on each lobe of the anterior margin; poste-

[1] This study was aided by a grant from the American Association for the Advancement of Science through the Illinois State Academy of Science. The writer is deeply indebted to Dr. J. C. Chamberlin for the privilege of examining and recording herein the Illinois pseudoscorpions in his private collections.

[2] While the present publication was being prepared, the writer received from Dr. J. C. Chamberlin a manuscript copy of a paper written by Dr. Chamberlin and scheduled to appear soon in the University of Utah Series. In this paper, Dr. Chamberlin gives an excellent description of *V. spinosa*. In order to indicate the limits of variation in our Illinois specimens, the present writer gives here a short description of *V. spinosa* even though it duplicates to some degree the description being published by Dr. Chamberlin.

rior carapacal margin with 8-10 setae; total setae on carapace 95-110, usually about 100; length of carapace between 0.4 and 0.45 mm., usually closer to the latter; greatest width of carapace about 0.36 mm. Tergites except the first with a double row of setae; formula[3] for tergal chaetotaxy of first six tergites as follows: 10-11:3-4/11-13:3-5/10-13:2-6/11-13:5-8/11-15:6-9/11-14.

Chelicera stout; length 0.22-0.25 mm., base 0.125-0.135 mm. wide; external or dorsal surface often bearing many minute spinules, ventral surface smooth; movable finger subequal to the width of the base; base with either five or six setae, the right and left chelicerae of the same individual often exhibiting this variation; serrula exterior with 15 ligulate plates.

Palp with granulate surface; setae numerous; trochanter usually between 0.145 and 0.16 mm. long, width 0.095-0.105 mm., length 1.5 to 1.65 times the width; femur 0.4-0.46 mm. long, 0.09-0.105 mm. wide, length 4.4 to 4.7 times the width; tibia 0.195-0.215 mm. long, width as in the femur, length 2.05 to 2.15 times the width; chela including pedicle 0.6-0.7 mm. long, 0.11-0.13 mm. wide; length usually 5.1 to 5.2 times the width but in one individual 5.5 times; depth of chela subequal to the width; length of hand with pedicle 0.23-0.27 mm.; length of movable finger 0.36-0.42 mm. Fixed finger with 10 to 12 well-spaced and acute teeth along the distal half of the finger and usually 18 to 20 (in one individual only 14) subcontiguous and contiguous teeth placed more proximal; movable finger with 28 to 30 flatly rounded and more or less contiguous teeth. Tactile setae as indicated in figure 2.

Legs of first pair almost smooth, distal three podomeres very setaceous; pars basalis subcylindrical, 0.24-0.265 mm. long, length a little more than four times the depth; pars tibialis with both margins slightly convex to almost straight, length 0.17-0.18 mm., 3 to 3.4 times the depth; tibia subcylindrical, 0.135-0.155 mm. long, 3.2 to 3.6 times the depth; tarsus a little curved in some individuals, 0.24-0.28 mm. long, depth 0.34 0.35 mm., length between 7 and 8 times the depth. Each coxa of the first and second legs with a cteniform row of four or five ligulate and terminally incised spines. Fourth leg with tibia, pars tibialis, and metatarsus very granular; setae abundant especially on the distal podomeres; pars basalis with almost straight to weakly convex flexor margin, extensor margin markedly convex, length 0.17-0.195 mm., 1.3 to 1.4 times the depth; pars tibialis with both margins a little convex, the extensor flatly so, length 0.21-0.24 mm., about 1.8 times the depth; tibia with flexor margin evenly convex, extensor margin distally straight, length 0.27-0.3 mm., 3.85 to 4.05 times the greatest depth just distal to the center; metatarus subcylindrical, 0.125-0.14 mm. long, about 2.8 times the depth; telotarsus 0.27-0.32 mm. long, 8 to 8.5 times the depth.

FEMALE: (Description based on two females.) Much like the male except slightly larger and more tergal setae; body length 1.1-1.3 mm.; chaetotaxy of tergites 1 through 6 as follows: 11-17:6-8/13-17:6-11/13-17:8-13/13-20:10/14-18:10-15/14-18.

[3] In this formula, the minimum and maximum number of setae observed for any entire row are separated by a short line; the rows (if more than one row occurs) of a single tergite are separated by a diagonal line with the anterior row preceding the line and the posterior row following; the setae of each tergite are separated from those of the preceding and succeeding tergites by colons.

Chelicera 0.25 mm. long, finger length 0.135-0.14 mm. Palp with podomeres slightly larger than in the male, length : width ratios virtually identical in the two sexes; length of trochanter 0.16 0.175 mm., femur about 0.5 mm., tibia 0.215-0.24 mm., chela 0.7-0.75 mm., hand 0.275-0.295 mm., finger about 0.45 mm. Legs (measurements based on one female) much as in the opposite sex except podomeres slightly larger. First leg with pars basalis 0.31 mm. long, 4.4 times the depth; pars tibialis 0.205 mm. long; tibia 0.165 mm. long; tarsus about 0.29 mm. long, 7.6 times the depth. Fourth leg with podomeres of the following lengths: pars basalis 0.215 mm., pars tibialis 0.265 mm., entire femur 0.46 mm., tibia 0.34 mm. (4.25 times the depth), metatarsus 0.155 mm., telotarsus 0.34 mm.

TRITONYMPH: (Based on a single individual.) In general somewhat like the adult; setae fewer; appendages stouter. Chelicera with serrula exterior of 14 plates; movable finger (fig. 3) with two simple galea-like processes inserted close together between the base of the galeal seta and the finger tip, these processes having a marked significance since a galea is not present in the adult. Three to four coxal spines on each coxa of the first and second legs. Palp with femur 0.35 mm. long, 0.08 mm. wide; tibia about 0.17 mm. long, 0.09 mm. wide; chela including pedicle about 0.55 mm. long, 0.11 mm. wide; hand with pedicle 0.2 mm. long; movable finger 0.33 mm. long. Movable finger with tactile setae *t*, *st*, and *sb* related much as in the adult and with the first two distal to the midpoint of the finger; *b* wanting; finger with about 25 rounded and poorly developed marginal teeth. Fixed finger with tactile setae more or less as in the adult except *it* and *est* closer together; dorsum of hand with one tactile seta (*isb* or *ib*), the other of the pair wanting; about 15 rounded basal teeth and 13 acute distal teeth.

Family Chthoniidae Hansen

Apochthonius moestus (Banks, 1891) Chamberlin, 1929

(Figs. 4-7)

RECORDS: Besides the records previously given (Hoff, 1944) for this species from Illinois, *A. moestus* is now reported in the following 21 collections: Adams Co. (7 collections by the writer), Union Co. (3), Pope Co. (2), Madison Co. (1), Champaign Co. (1), Bond Co. (2), LaSalle Co. (3), Jersey Co. (1), and Hardin Co. (1). In addition, Dr. Chamberlin's collections include a series of individuals taken by Dr. Jane Claire Dirks at White Heath, Piatt Co., Illinois, during 1938.

In the writer's previous publication (1944), a statement was made regarding the use for species recognition of the two tactile setae of the dorsal surface of the chelal hand, there being known at that time only two species of pseudoscorpions from the State with this characteristic. Other species with this characteristic have now been found in Illinois. *A. moestus*, however, is easily recognized by its size (greater than 1.3 mm., except in very few individuals), the contiguous teeth of the chelal fingers, and the presence of three spines on each of the first coxae.

While there is some information (Hoff, 1944, 1945b) relative to the characteristics of the adults of this species from Illinois, no record or description has been given for the immature stages. Fortunately, the present series of collections includes numerous nymphs of several stages

TABLE SHOWING IMPORTANT CHARACTERISTICS OF THREE NYMPHAL STAGES AND THE ADULT OF *APOCHTHONIUS MOESTUS*

	Protonymph	Deutonymph	Tritonymph	Adult (both sexes)
Body length	0.67 mm.	0.72-0.9 mm.	1.1-1.3 mm.	1.3-1.8 mm.[2]
Carapace length	0.25 mm.	0.28-0.32 mm.	0.32-0.4 mm.	0.32-0.42 mm.[2]
Serrula exterior, number of plates	11	12	14	16-17
Coxa I, number of spines	0	1	2	3[2]
Palpal femur length	0.17 mm.	0.20-0.24 mm.	0.30-0.35 mm.	0.32-0.5 mm.
width	0.055 mm.	0.06-0.07 mm.	0.075-0.09 mm.	0.08-0.11 mm.[2]
l/w ratio	3.1	3.2-3.6	3.8-4.0	3.5-4.5
Palpal tibia length	0.11 mm.	0.125-0.14 mm.	0.17-0.21 mm.	0.20-0.24 mm.[2]
width	0.072 mm.	0.075-0.085 mm.	0.095-0.12 mm.	0.105-0.145 mm.
l/w ratio	1.55	1.6-1.7	1.8	1.6-1.9
Chela length	0.29 mm.	0.35-0.38 mm.	0.5-0.56 mm.	0.55-0.75 mm.
width	0.083 mm.	0.088-0.1 mm.	0.11-0.135 mm.	0.12-0.17 mm.
l/w ratio	3.5	3.8-4.1	4.1-4.5	4.0-4.7
Finger length	0.2 mm.	0.24-0.255 mm.	0.33-0.38 mm.	0.37-0.46 mm.[2]
Movable finger tactile setae	1	2	3	4
marginal teeth	30 (*circ.*)	40 (*circ.*)	45 (*circ.*)	50-60
Fixed finger tactile setae[1]	3	7	8	9
marginal teeth	30 (*circ.*)	45 (*circ.*)	50 (*circ.*)	50-70

[1] Includes the tactile setae of the dorsum of the hand and the double seta *(xs)* when these occur.
[2] A few individuals may fall outside of these ranges.

EXPLANATION OF FIGURES

Drawings are outlined with the camera lucida from specimens cleared in beechwood creosote and mounted in Canada balsam.

Verrucaditha spinosa. Fig. 1. Dorsal view of palp, male; tactile setae of movable finger omitted; scale equals 0.25 mm.—Fig. 2. Lateral view of chela, male; scale as in Fig. 1.—Fig. 3. Movable finger of chelicera, tritonymph, scale equals 0.05 mm.

Apochthonius moestus. Fig. 4. Lateral view of chela, protonymph.—Fig. 5. Lateral view of chela, deutonymph.—Fig. 6. Lateral view of chela, tritonymph.—Fig. 7. Lateral view of chela, female adult. Figures 4 through 7 drawn to the scale in fig. 1.

Chthonius tetrachelatus. Fig. 8. Lateral view of chela, male; scale equals 0.25 mm.

Larca granulata. Fig. 9. Dorsal view of palp male; tactile setae of movable finger omitted; scale equals 0.5 mm.—Fig. 10. Lateral view of chela, male; scale as in fig. 9.

b, basal seta of movable finger
eb, external basal seta of fixed finger
esb, external subbasal seta of fixed finger
est, external subterminal seta of fixed finger
et, external terminal seta of fixed finger
ist, internal subterminal seta of fixed finger
it, internal terminal seta of fixed finger
sb, subbasal seta of movable finger
st, subterminal seta of movable finger
t, terminal seta of movable finger
xs, double seta of fixed finger

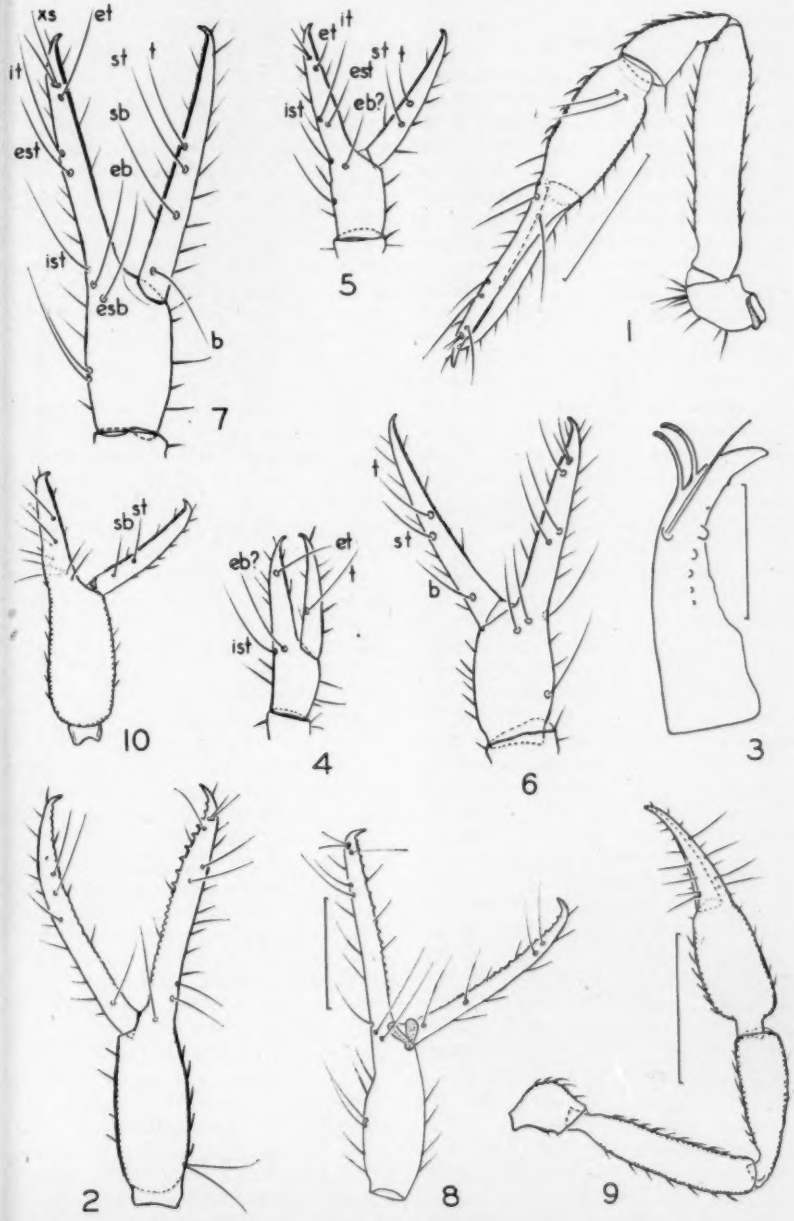
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PLATE I.

taken in collections made from May through September. These nymphs demonstrate interesting progressive changes which occur from one instar to the next. These changes include a gradual increase in the number of coxal spines on each of the first coxae and an increase in the number of tactile setae on the chelal fingers. The brief descriptions given here in addition to the accompanying table serve to indicate these and other interesting changes.

NYMPHS: A single individual of the earliest nymphal stage, the protonymph, was found in a collection taken by the writer on July 2, 1944, from an area near Quincy. In the same collection was a female *A. moestus* and several later nymphs of the same species. The protonymph is characterized by having very stout and little sclerotized appendages, by a lack of coxal spines on the first coxae, and by the presence of very few tactile setae on the chelal fingers. The positions of the tactile setae are of particular interest. The single tactile seta (very probably *t*, as indicated by its position approximate to the finger margin) is located a little proximal to the midpoint of the movable finger; on the fixed finger, *et* is located just within the distal one-third of the finger, two other tactile setae (possibly *ist* and *eb*) are located at the base of the finger; and one of the future setae of the dorsum of the chelal hand appears to be marked by a prominent seta without, however, the characteristic areole. The marginal teeth of the chelal fingers in this early instar vary from slender and acute teeth at the distal end of each row to rounded and flattened teeth at the proximal end of the row; the teeth are in general more slender and acute than in the adult.

The next stage available for study is the deutonymph, several of these being found in six collections. The earliest date of collection of the deutonymph was June 15 and the latest September 30. This instar has a larger size and more slender appendages than the protonymph described above. This is shown clearly in the table. There is a single spine on each first coxa. The movable finger has two tactile setae, *t* just proximal to the midpoint of the finger and *st* about three areolar diameters distal to *t*; fixed finger with a double seta (*xs*) and five tactile setae on the finger; one seta (*ib* or *isb?*) on the dorsum of the hand; *et* about one-third of the finger length from the finger tip and about one areolar diameter proximal to *xs*, two setae (*est* and *it*) at about two-thirds of the finger length from the tip, and two others (*ist* and either *esb* or *eb*) near the base of the finger. The marginal teeth of the chelal fingers shaped much as in the earlier nymph but greater in number; the teeth do not extend entirely to the base in the movable finger but cover almost the entire finger margin in the fixed finger.

Two tritonymphs were available for study. One was found in a collection made on Sept. 30 and the other in a collection taken on May 23. The tritonymphs are larger than the deutonymphs and have more slender appendages. The coxal spines have increased to two and additional tactile setae are present on the chelal fingers. The movable finger has three setae: *t* just distal to the midpoint of the finger, *st* just proximal to the midpoint of the finger, *t* and *st* separated by about the width of the finger at the level of *t*, *b* basal in position and separated from the basal margin of the finger by a distance equal to the width of the finger at the level of *b*, *sb* wanting. Fixed finger with tactile setae much as in

the adult except only one seta (*isb* or *ib*?) occurs on the dorsum of the hand.

Chthonius (Ephippiochthonius) tetrachelatus (Preyssler, 1790) Stecker, 1875
(Fig. 8)

RECORDS: This species has been taken in eleven collections made by the writer from several places along the Mississippi River bluffs near Quincy, Adams Co., Illinois. A single individual was also available to the writer from a collection (Chicago Natural History Museum) made by Henry Dybas from near Moosehart, Kane Co., Illinois. Since this species is found over a wide area in Europe and has been reported frequently from eastern United States as far west as Indiana, it seems strange that it has not been taken from other Illinois areas.

Chthonius tetrachelatus is fairly abundant as to number of individuals whenever taken and most collections contain both nymphs and adults. With exception of the Kane Co. specimen for which no ecological data are available, the collections have been made from debris, leaf mold, and loam. In each instance, limestone outcrops are in the immediate vicinity. The habitat in Adams County is somewhat similar to the habitat in Europe where Kästner (1929) reports this species as living under fallen leaves and stones in the forest, the nests being made on the underside of the stones. Its particular habitat might explain why it has not been found in collections from other sections of Illinois.

Our individuals agree well with the descriptions given for this species in the literature except that the cheliceral finger seems to be somewhat shorter than indicated by some writers (Hadzi, 1933). With respect to recognition of this species, the following combination of characteristics may prove useful: coxal spines present on second and third coxae; two tactile setae on the dorsum of the hand; palpi very slender; from the side, the dorsal margin of the chelal hand shows a marked depression between the tactile setae and the base of the fixed finger; the marginal teeth of the chela are acute and widely separated at least along the distal end of the row on each finger.

Suborder
DIPLOSPHYRONIDA
Chamberlin

Family Neobisiidae Chamberlin

Microbisium brunneum (Hagen, 1869) Chamberlin, 1930

RECORDS: In addition to records previously published (Hoff, 1944), the following new records are given: Adams Co. (11), Bond Co. (2), Boone Co. (1), Calhoun Co. (1), Carroll Co. (1), Champaign Co. (3), Coles Co. (1), Cook Co. (4), DuPage Co. (1), Fulton Co. (1), Jackson Co. (1), Jersey Co. (1), Jo Daviess Co. (1), Lake Co. (11), La Salle Co. (5), Lee Co. (1), Madison Co. (2), Mason Co. (3), Mercer Co. (1), Ogle Co. (1), Piatt Co. (1), Pope Co. (3), Putnam Co. (1), Schuyler Co. (1), Union Co. (2). While most of these records are based on collections of the State Natural History Survey, a few are records of specimens collected by the writer and specimens kindly supplied by Dr. Chamberlin.

Family Garypidae Hansen, 1894

Larca granulata (Banks, 1891) Chamberlin, 1930
(Figs. 9-10)

RECORDS: Five collections from Starved Rock State Park, LaSalle Co. and one collection from near Fountain Bluff, Jackson Co.

This species is apparently restricted in habitat, being found in Starved Rock State Park only in association with debris on sandstone ledges and shelves. No ecological data are available for the Jackson Co. collection. In this connection, it is interesting to note that the type specimens were "Found in crevices of a cliff at Ithaca, N. Y." (Banks, 1891). With the exception of the publication of a drawing by Ross (1944), no records have been published of the occurrence of this species outside of New York State. The drawing of the Illinois specimen as published by Ross (1944, fig. 56) was through an unfortunate clerical error incorrectly designated as an individual of the vastly different species *Chernes dentatus*.

Larca granulata can be recognized easily by the very stout abdomen in which the width is nearly equal to the length, by the triangular carapace, and by the characteristic shape of the palp.

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EFFECT OF TEMPERATURE UPON THE EXPRESSION OF ADORSO-CENTRAL A BRISTLE REDUCING MUTUANT OF *DROSOPHILA MELANOGASTER*

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In February of 1932 while examining a forked (*f*) infra-Bar (B^1) stock of *Drosophila melanogaster* which were being kept at 27°C. it was noted that several of the flies among both the males and the females lacked either one or both of the anterior dorso-central bristles. The flies which showed the characteristic were mated together and their offspring examined for its presence. It was noticed that dorso-centrals were missing in only a certain percentage of the flies at 27°C., indicating that at this temperature penetrance was not complete. Inbreeding and selection were followed until it was certain that the stock was genetically pure. The new mutant was tentatively named adorso-central using the symbol *adc* for the gene or factor involved. This name seems appropriate since it describes the chief somatic effect, the loss of dorso-central bristles. Usually one or the other, frequently both, of the anterior dorso-centrals are missing. Rarely the posterior ones are gone, sometimes with, sometimes without, the accompanying loss of the anteriors. Usually when a bristle is lacking the basal ring is also missing but occasionally the ring will be present without the bristle.

The original stock in which the mutation occurred carried forked (*f*) a bristle affecting gene which causes gnarling and bending of the bristles and also results in forked ends on many. It also carried infra-Bar (B^1) which reduces the facet number in the eye. A normal eyed straight bristle stock carrying *adc* was established by crossing the *adc f* B^1 to wild type. From these matings it appeared that the mutant is completely recessive to normal. There was also a suggestion from these matings, which were not completely recorded, that the mutant may be sex-linked. It may turn out to be another one of the many scute (*sc*) alleles. After the establishment of the adorso-central by itself, it has been kept as one of the stocks in our laboratory for examination and study. The position and linkage relationships of the mutant are being worked out and when established will be published.

The experiments dealt with in this report are concerned with the effects of temperature upon the expression of this mutant. The flies were raised at constant temperatures of 17°, 22° 24°, and 28° C. The temperature control for the 17°, 22°, and 28° incubators was accurate to plus or minus 0.3°. For the 24° incubator the control was accurate within plus or minus 0.5°. The flies used for the parents had been inbred for two years before the experiments were begun and should, therefore, have been as homozygous as is practicable. The same set of parents produced the flies raised at all of the temperatures. The same batch of food was also used for all tempera-

TABLE 1.—PERCENTAGE OF FLIES WITH ONE OR MORE ANTERIOR DORSO-CENTRAL BRISTLES LACKING WHEN RAISED AT DIFFERENT CONSTANT TEMPERATURES

	17°C.		22°C.		24°C.		28°C.	
	Females	Males	Females	Males	Females	Males	Females	Males
Number of individuals	100	100	100	100	100	100	100	100
Percent lacking anterior dorso-centrals.....	2	0	6	22	14	28	72	88

tures, and all other environmental factors were as accurately controlled as possible. The results obtained are summarized in table 1.

The table shows clearly that at 17° the penetrance of the *adc* factor is extremely low, only two females out of a hundred and no males out of the same number lacked bristles. At 22° the penetrance is still low and even at 24° it is not very high. At 28°, however, 72 percent of the females and 88 percent of the males lacked one or more bristles. The table also clearly brings out that at all temperatures except 17° the penetrance is higher in the males than it is in the females.

When the frequency of the loss of the right anterior dorso-central is compared with that of the left the data show no significant difference between the two sides of the fly in this respect. Thus there were in the whole series 174 flies in which the right anterior was missing and 160 flies with the left anterior missing. Assuming that these two events should occur with equal frequency there is a difference between observed and expected of 7 with a standard error of 8.97. This would clearly indicate that the departure from the assumed equal frequency is certainly not significant since a departure as great or greater would be expected 40 percent of the time due to chance alone.

The *adc* mutant appears to be promising material for the further study of both temperature and genetic effects. A more extended and critical analysis is now being attempted.

PARASITES OF AMPHIBIA. BUFONIDAE: PROCOELA: SALIENTIA. I.

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The amphibia play such an important part in the laboratory study of biology, and so many parasites are found in them by students and by research workers that it seems of value to present a check list of some of the more frequently recorded parasites in the hope that recognition of the parasites might be somewhat easier. This is the thirteenth of a series of such lists that attempts to cover the entire amphibian group, and includes all of the Bufonidae except the members of the Bufoninae. This group is recorded elsewhere.

BUFONIDAE

The Bufonidae are divided into the sub-families Bufoninae (Cosmopolitan), Criniinae (Austral-asia), Elosiinae (mainly in Brazil), Heleophryninae (S. Africa), Leptodactylinae (S. America and Caribbean Is.), Pseudinae (S. America and Caribbean area) and Rhinophryninae (Mexico).

Among the Criniinae (Austral-asia) the following forms have been reported as being hosts to various parasites (7 genera with 11 spp.)

1. CHIROLEPTES BREVIPALMATUS: *Brachysaccus juvenilis* (Trematoda).
2. CRINIA SIGNIFERA: *Protoopalina tenuis* (Protozoa); and *Batrachomyia* sp? of Macleay, 1863 (Dipteran larva).
3. HELIOPORUS ALBOPUNCTATUS: *Filaria cochleata* (Nematoda).
4. LIMNODYNASTES DORSALIS: *Cosmocerca australiensis, C. limnodynastes, C. propinqua, Oswaldocruzia limnodynastes,* and larval *Physaloptera confusa* (Nematoda); *Dolichosaccus ischyrus* (Trematoda); *Entamoeba morula, Nyctotherus cordiformis, N.* sp? of Cleland & Johnston, 1910, *Opalina* sp? of C. & J., 1910, *O.* sp? of Metcalf, 1923, *Protoopalina acuta, P. dorsalis, P. intestinalis,* and *Zelleriella binucleata* (Protozoa); and *Bacillus* sp? of Willis, 1932 (Bacteria).
5. L. ORNATA: *Trypanosoma rotatorium, T.* sp? of Cleland & Johnston, 1910, and *T.* sp? of Laveran & Mesnil, 1912 (Protozoa).
6. L. PERONII: *Rhabdias hylae* (Nematoda); *Brachysaccus anartius, Dolichosaccus tryphesus, Gorgodera australiensis, Haematoloechus australis,* and *Opisthodiscus subclavatus* (Trematoda); and *Nyctotherus* sp? of Cleland & Johnston, 1910, *Opalina* sp? of C. & J. 1910, *O.* sp? of Metcalf, 1923, and *Protoopalina peronii* (Protozoa).
7. L. TASMANIENSIS: larval *Physaloptera confusa,* and *Rhabdias hylae* (Nematoda); *Opisthodiscus subclavatus* (Trematoda); and *Entamoeba morula, Trypanosoma clelandii, T. rotatorium, T.* sp? of Cleland & Johnston, 1910, *T.* sp? of Laveran & Mesnil, 1912, and *Zelleriella binucleata* (Protozoa).
8. NOTADEN BENNETTI: *Balantidium* sp? of Metcalf, 1923 (Protozoa).
9. PSEUDOPHRYRYNE BIBRONI: larval *Paryphostomum tenuicolle* (Trematoda); *Protoopalina bibronii* (Protozoa); and *Batrachomyia* sp? of Macleay, 1863 (Dipteran larva).
10. UPEROLEIA MARMORATA: *Nematotaenia* sp? of Johnston, 1916 (Cestoda); and *Batrachomyia* sp? of Macleay, 1863 (Dipteran larva).
11. U. sp?: *Trypanosoma rotatorium* (Protozoa).

[1] Contributions from the Biological Laboratories of Knox College, No. 101.

Among the Elosiinae (mainly Brazilian forms) the following 2 genera with 4 species have been reported as hosts to various parasites:

1. CROSSODACTYLUS GAUDICHAUDII: *Capillaria recondita* (Nematoda.)
2. ELOSIA NASUS: *Aplectana micropenis, A. vellardi, Cosmocerca parva,* and *Spironoura mascula* (Nematoda); and *Dolichosaccus amplicava,* and *Gorgoderina cedroi* (Trematoda).
3. E. PARVA: *Cosmocerca parva* (Nematoda).
4. E. RUSTICA: *Strongyloides pereirai* (Nematoda).

Among the Heleophryninae (S. African forms) the following genus with 3 spp. have been reported as hosts to protozoan parasites:

1. HELEOPHRYNE PURCELLI: *Protoopalina heleophrynes* (Protozoa).
2. H. REGIS: *Protoopalina capensis* (Protozoa).
3. H. ROSEI: *Protoopalina heleophrynes* (Protozoa).

Members of the Leptodactylinae (S. America and the Caribbean Is.) are in greater abundance and therefore are more often studied. 7 genera with 24 spp. have been reported as parasitized with a wide range of animal and plant forms.

1. EUPEMPHIX MARMORATUS: *Filaria bufonis* (Nematoda).
2. E. NANA: *Zelleriella dubia* (Protozoa).
3. E. NATTERERI: unidentified larvae (Cestoda).
4. E. TRINITATIS: *Balantidium* sp? of Metcalf, 1923 (Protozoa).
5. LEPTODACTYLUS ALBILABRIS: larval *Diphyllobothrium erinacei* (Cestoda); and *Zelleriella leptodactyli* (Protozoa).
6. L. CALIGINOSUS: *Aplectana* sp? of Travassos, et al., 1939, and *Rhabdias* sp? of T., et al., 1939 (Nematoda); *Catadiscus marinholutzi, C.* sp? of T., et al., 1939, and *Glypthelmins* sp? of T., et al., 1939 (Trematoda); and *Nyctotherus barberoi, Zelleriella leptodactyli,* and *Z. meneendzi* (Protozoa).
7. L. GRACILIS: *Strongyloides carinii* (Nematoda); and *Nyctotherus bertarelli, Proteromonas longifila,* and *Zelleriella leptodactyli* (Protozoa).
8. L. MICROTIS: *Balantidium* sp? of Metcalf, 1923, *Nyctotherus* sp? of M., 1923, and *Zelleriella leptodactyli* (Protozoa).
9. L. MISTACEUS: *Nyctotherus heteronucleatus* (Protozoa).
10. L. OCELLATUS: *Agamonema ranae, Ascaris leptodactyli, Cosmocerca* sp? of Travassos, et al., 1939, *Eustrongyloides* sp? of T., et al., 1939, *Foleyella convoluta, F. scalaris, F.* sp? of T., et al., 1939, *Hedruris scabra, "Microfilaria" tamborini, M.* sp? of Wenyon, 1934, *Multicaecum* sp? of T., et al., 1939, *Oswaldocruzia filiformis, O. lopezi, O. sub-auricularis, Oxyascaris similis, Oxysomatium membranosa, Rhabdias* sp? of Leiper, 1934, *Schulzia subventricosa,* and *Spironoura nitida* (Nematoda); *Catadiscus inopinatus, C. marinholutzi, C. uruguayensis, C.* sp? of Travassos, et al., 1939, *Choledocystus eucharis, Glypthelmins elegans, G. linguatula, G. parva, G. proximus, G. repandum, G. simulans, G.* sp? of T., et al., 1939, *Gorgoderina cryptorchis, G. parvicava, Haematoloechus neivai, H. ozorioi, Halipegus dubius,* larval *Hysteromorpha trilobum,* and *Plagiorchis lenti* (Trematoda); *Cylindrotaenia amerinana,* larval *Cysticercus ocellatus,* larval *Ichthyotaenia* sp? of Parona, 1901, *Sparganum leptodactyli,* and larval *Taenia* sp? of Parona, 1900 (Cestoda); *Centrorhynchus giganteus, C. tumiclulus,* and *Lueheia luehei* (Acanthocephala); *Cariniella carinii, Cepedea rubra, Eimeria leptodactyli, Haemogregarina leptodactyli, H.* sp? of Franca, 1917, *H.* sp? of Plimmer, 1912, *Hegneria leptodactyli, Leptotheca chagasi, Myxidium immersum, M. lindoyense,* ? *Nyctotherus cordiformis, N. cunhai, N. gibber, N. loricatus, N. pavlistanus* (in tadpoles, *N. tejerai, N. vorax, Toxoplasma cuniculi* (experimentally), *Trichomonas batrachorum, Trypanosoma arcei, T. celestinoi, T. leptodactyli, T. ocellati, T. rotatorium, T.* sp? of Carini, 1907, *T.* sp? of Laveran & Mesnil, 1912, *T.* sp? of Wenyon, 1934, *Zelleriella antilliensis, Z. antunesi, Z. brasiliensis, Z.*

caudata, Z. corniola, Z. cornucopia, Z. cornucopioide, Z. cuneata Z. excavata, Z. foliacea, Z. magna, and *Z. truncata* (Protozoa); *Haemobartonello ranarum* (n. comb. for *Bartonella ranarum* Zavattari & Defendi, 1931) (Bacteria); and *Hannemania argentina,* and *H. hepatica* (Acarina).

11. L. PENTADACTYLUS: *Foleyella convoluta, Schrankia brasili, S. larvata,* and *S. schranki* (Nematoda); larval *Alaria alata, Gorgoderina parvicava,* and larval *Strigea vaginata* (Trematoda); and *Bertarellia leptodactyli, Haemogregarina heteronucleata,* ? *Nyctotherus cordiformis, N. cunhai, N. gibber, N. loricatus, N. tejerai, Zelleriella cornucopia, Z. ovonucleata,* and *Z. truncata* (Protozoa).
12. L. PROGNATHUS: *Myxidium immersum,* and *Zelleriella antilliensis* (Protozoa).
13. L. SIBILATRIX: *Nyctotherus oswaldoi, Zelleriella magna,* and *Z. truncata* (Protozoa).
14. L. TYPHONIUS: *Aplectana acuminata, A.* sp? of Travassos, et al., 1939, *Cosmocerca commutata,* and *Foleyella convoluta* (Nematoda); and *Opisthodiscus subclavatus* (Trematoda).
15. L. spp?.: *Trypanosoma borrelli,* and *T. rotatorium* (Protozoa). *Oswaldocruzia pipiens* (Nematoda) has been reported from a Leptodactylid kept in a Zoological Garden in the United States.
16. LIMNOMEDUSA MACROGLOSSA: *Myxidium immersum,* ? *Nyctotherus cordiformis, and Zelleriella antilliensis* (Protozoa).
17. -PALUDICOLA FALCIPES: *Cepedea rubra* (Protozoa).
18. P. FUSCOMACULATUS: *Cosmocerca* sp? of Travassos, et al., 1939 (Nematoda); and unidentified larvae (Cestoda).
19. PHYSALAEMUS SIGNIFERUS: *Entamoeba* sp? of Chen & Stabler, 1936, *Myxidium lindoyense, Nycototherus paludicolae, Zelleriella brasiliensis, Z. paludicolae,* and *Z.* sp? of Brumpt & Lavier, 1936 (Protozoa).
20. PLEURODEMA (= Paludicola) BIBRONI: *Balantidium* sp? of Metcalf, 1923. *Myxidium immersum,* ? *Nyctotherus cordiformis, N.* sp? of Metcalf, 1923, *Trichomonas augusta, Zelleriella antilliensis, Z. paludicolae,* and *Z.* sp? of Chen & Stabler, 1936 (Protozoa); and *Hannemania samboni* (Acarina).
21. P. BRACHYOPS. *Zelleriella paludicolae* (protozoa).
22. P. BUFONINA: *Zelleriella patagoniensis* (Protozoa); and *Hannemania hobdayi* (Acarina).
23. P. DARWINI: *Acanthocephalus lutzii* (Acanthocephala).
24. PSEUDOPALUDICOLA AMEGHINI: *Cepedea rubra* (Protozoa).

The Pseudinae (S. American and Caribbean forms) are represented by 20 species of 5 genera for which parasites have been reported.

1. CALYPTOCEPHALUS GAYI: *Trichomonas augusta* (Protozoa).
2. CERATOPHRYS AMERICANA: *Myxidium immersum,* and *Nyctotherus ceratophris* (Protozoa).
3. C. CORNUTA: *Ascaris foecunda, Oswaldocruzia subauricularis,* and *Schulzia subventricosa* (Nematoda).
4. C. DORSATA: *Oswaldocruzia filiformis, O. subauricularis,* and *Oxysomatium baylisi* (Nematoda).
5. C. ORNATA: immature *Taenia ceratophrys* (Cestoda).
6. ELEUTHERODACTYLUS BINGHAMI: *Zelleriella binghami* (Protozoa).
7. E. BINOTATUS: *Aplectana* sp? of Travassos, 1925 (Nematoda).
8. E. FOOTEI: *Zelleriella cusconis* (Protozoa).
9. E. GOLLMERI: *Aplectana pintoi, A. vellardi, A.* sp? of Travassos. 1925, *Cosmocerca brasiliensis, Oswaldocruzia subauricularis,* and *Schulzia subventricosa* (Nematoda); and *Hannemania stephensi* (Acarina).
10. E. GÜNTHERI: *Cepedea* sp? of Metcalf, 1940 (Protozoa).
11. E. LEPTOPUS: *Protoopalina diplocarya* (Protozoa).
12. E. LUTEOLUS: *Protoopalina xanachana* (Protozoa).
13. E. MILIARIS: *Aplectana vellardi, A.* sp? of Travassos, 1925, *Cosmocerca brasiliensis,* and *Schulzia subventricosa* (Nematoda); and *Zelleriella* sp? of Metcalf, 1940 (Protozoa).
14. E. RICORDII (Florida): *Aplectana* sp? of Walton, 1940 (Nematoda); and *Hannemania penetrans* (Acarina).
15. E. sp?: *Hannemania hylodeus* (Acarina).

16. E. sp? tadpoles: *Cepedea* sp? of Metcalf, 1940 (Protozoa).
17. PSEUDIS MANTIDACTYLA: *Myxidium immersum*, ? *Nyctotherus cordiformis*, and *Zelleriella antilliensis* (Protozoa).
18. P. PARADOXA: *Catadiscus pygmaeus*, *Gorgoderina parvicava*, and *Haematoloechus neivai* (Trematoda).
19. TELMATOBIUS ESCOMELI: "*Abibes*" sp? of Escomel, 1929, *Hexamita brumpti*, "*Monadiens*" sp? of Escomel, 1929, *Nyctotherus* sp? of Escomel, 1929, *Opalina ranarum*, *Trichomonas batrachorum*, and *T. "hominis"* of Escomel, 1929 (Protozoa).
20. T. JELSKII: "*Abibes*" sp? of Escomel, 1929, *Hexamita brumpti*, "*Monadiens*" sp? of Escomel, 1929, *Nyctotherus* sp? of Escomel, 1929, *Opalina ranarum*, *Protoopalina longinucleata*, *Trichomonas batrachorum*, *T. "hominis"* of Escomel, 1929, *T. "intestinalis"* of Escomel, 1929, and *Zelleriella telmatobii* (Protozoa).

Examinations of members of the Rhynophryninae (Mexican forms) have not as yet resulted in the recording of the presence of any parasitic infestations.

PHENOTHIAZINE-SALT MIXTURES AS AN ANTHELMINTIC FOR SHEEP

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Since Harwood and associates (1939) of the Bureau of Animal Industry demonstrated the efficiency of phenothiazine in removing various species of nematodes, the efficiency of this chemical for removing intestinal parasites of sheep has been confirmed by many other investigators. The Illinois Experiment Station reported in 1941, 1942a, and 1942b, favorable results as judged by Stoll counts following the treatment of sheep, goats, and horses for strongyles. At the Illinois Station phenothiazine had been administered to parasitized lambs in gelatine capsules, boluses, liquid, blackstrap molasses, and soya bean pellets.

Since the effectiveness of phenothiazine has been demonstrated in removing nodular worms, stomach worms, and bankrupt worms of sheep, attempts have been made to simplify the methods of administering the drug to them. One of the most popular of the suggestions has been the incorporation of the chemical with salt and offering the mixture as a lick. Habermann and Shorb found phenothiazine-salt mixtures in proportions of from 1:9 to 1:14 to be effective in reducing the larval counts in fecal cultures. The average daily consumption of phenothiazine was at least 0.5 gram per sheep. Earlier, Shorb and Habermann pointed out that daily administration of 0.5 gram doses of the drug completely inhibited the development of all nematode larvae with the exception of *Strongyloides papillosus*. Viable larvae again appeared in the fecal cultures 48 hours after withdrawal of the drug. The egg count was not at any time reduced. Gordon arrived at essentially the same conclusions. Britton, Miller, and Cameron in an uncontrolled observation with 830 ewes and lambs reported a definite anthelmintic effect of a 1:15 phenothiazine-salt mixture. In a second and more comprehensive report involving controlled experiments, the same authors again reported favorably upon a 1:15 phenothiazine-salt mixture as a practical and effective anthelmintic for sheep. A 1:9 phenothiazine-salt mixture, according to Thorp and Keith, reduced the numbers of nematode ova in the feces of parasitized sheep. The elimination of ova remained low as long as the mixture was fed. Foster and Habermann recommend the use of mixtures containing from 9 to 14 parts of salt to one part of phenothiazine in the control of ovine nematodes. They caution, however, that the use of phenothiazine in salt should be regarded as a preventive rather than a therapeutic procedure.

This paper is an attempt to outline two years work (1943, 1944) at the Dixon Springs Experiment Station, Pope County, Illinois, to study the effectiveness of phenothiazine-salt mixture in controlling ovine nematodes on pasture.

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PLAN

In the 1943 tests approximately 600 mature western ewes, maintained at the Dixon Springs Experiment Station, were made available for the experiment. Early in January the sheep were brought in from pastures for dry lot feeding. They were divided at random into three lots of 196 ewes each. Each ewe was dosed with two ounces of a 50 percent suspension of phenothiazine in molasses and water. They had been dosed similarly for the preceding several months. Mixed hay (mainly lespedeza and grass) was fed to all lots, together with one pound of shelled corn and one-fourth pound of soybean oil meal daily per head. Beginning January 15 a 1:14 phenothiazine-salt mixture was made available to the ewes in Lot 3. They were also provided with a mineral mixture of equal parts limestone and bone meal. Lots 1 and 2 had access to a mixture of salt, limestone, and bone meal.

Lambing occurred in the three lots during February, March, and April. The experimental treatment of these lots of ewes and lambs was planned as follows: Lot 1, the control group, was to be maintained without further phenothiazine medication. Lot 2 was to be dosed with phenothiazine, one ounce per ewe, one-half ounce per lamb, at the beginning of the pasture season and thereafter maintained upon a 1:14 phenothiazine-salt mixture. Lot 3 was to be maintained continuously, both in the dry lot and at pasture, on the 1:14 phenothiazine-salt mixture. In order to limit losses however, it was planned to treat the sheep in any lot with a therapeutic dose when and if parasitism became marked.

The degree of parasitism was to be estimated by fecal examinations for the presence of nematode ova and by autopsy examinations of representative ewes and lambs at time of marketing. The rate of gain and general condition were to be determined by inspection and periodic weighing.

The pastures ranged from one hundred to three hundred acres in size. Because of an unusual amount of rain during the spring and early summer growth of forage was excellent and ample. With one exception the pasture for each lot was changed once a month.

FECAL EXAMINATIONS AND POST-MORTEM INSPECTION

At the beginning of the pasture season and continuing at monthly intervals throughout the spring and summer fecal specimens were collected from a random selection of 25 ewes and 25 lambs in each lot. A similar collection had been made from the ewes in Lot 3 early in January. Preliminary observations (flotation) showed nematode ova to be present, and a two-gram portion of each fecal sample was preserved with 2cc. of 25 percent formalin. The specimens were then returned to the Department of Animal Pathology Laboratory at Urbana for determination of the nematode ova present according to the Stoll technic. At the time of slaughter the intestines from representative animals were observed for the presence and the relative numbers of parasites and parasitic nodules. The abomasum was opened and a portion of the contents removed and preserved in formalin for nematode examination.

RESULTS

Clinical Observations and Relative Gains

The ewes, together with their lambs, were turned to pasture April 25. The system of pasture rotation is set forth in Table 1.

TABLE 1.—PASTURE ROTATION AMONG THE THREE LOTS OF EWES AND LAMBS

Time of pasture	Pasture				
	Elam Lot	South Lot	Phelps Lot	Wells Lot	Experiment 8 Lot
April 25–May 26	3	2	1	.....	.....
May 27–June 28	1	3	2	.....	.....
June 29–August 3	.....	3	1a 1b	2	1c

During the first month on pasture none of the sheep developed clinical manifestations of parasitism. It was expected however that the pasture occupied by the sheep in Lot 1, the untreated group, would become contaminated and that this pasture, subsequently occupied by the second lot, would serve to test the effectiveness of a 1:14 phenothiazine-salt mixture in protecting ewes and lambs from parasites when exposed to infection. The sheep and lambs of Lot 3, maintained continuously upon phenothiazine-salt mixture since January, were never exposed to similar infestation during the pasture season, although at the end of the first month on pasture they were placed on the pasture previously grazed by animals of Lot 2.

At the end of the second month on pasture, the ewes and lambs in Lot 2, given access to 1:14 phenothiazine-salt mixture but maintained for four weeks upon a contaminated pasture, had developed marked clinical manifestations of parasitism. The sacrifice of two ewes and one lamb from this group confirmed the diagnosis. All ewes and lambs in this lot were treated with phenothiazine and placed on clean pasture. Both ewes and lambs in Lot 1 also showed evidences of parasitism but not to the same degree as those in the second group. Lot 1 was divided into three groups as follows:

Group a—20 ewes and their 20 lambs were untreated.

Group b—62 ewes and 35 lambs were drenched with phenothiazine, one ounce per ewe, one-half ounce per lamb.

Group c—105 ewes and 107 lambs drenched as Group b and offered a 1:9 phenothiazine-salt mixture.

The ewes and lambs in Lot 3, maintained upon a 1:14 phenothiazine-salt mixture but not placed upon a pasture recently occupied by heavily parasitized, untreated sheep, remained in good condition. Their pasture was not changed after May 27 at which time they were put in the pasture occupied the previous month by sheep of Lot 2. The gains for the various pasture periods are given in Table 2.

Examination of the data in Table 2 indicates that both ewes and lambs in Lot 3, maintained continuously upon 1:14 phenothiazine-salt mixture, made satisfactory gains. As will be noted in Table 1, they followed Lot 2 in the pasture rotation and were kept on this same pasture until August 3. On the other hand,

TABLE 2.—AVERAGE INDIVIDUAL GAINS MADE BY EWES AND LAMBS BY PERIODS MAY 27 TO AUGUST 3—68 DAYS

Period	Lot 1			Lot 2		Lot 3	
	Group	Ewes lbs.	Lambs lbs.	Ewes lbs.	Lambs lbs.	Ewes lbs.	Lambs lbs.
May 27–June 27.....		+1.1	+5.7	—2.9	—7.9	+2.8	+11.5
June 28–August 3....	a	+14.5	+4.9	+8.7	+8.0	+20.2	+16.6
	b	+20.0	+17.4				
	c	+17.4	+17.6				

TABLE 3.—LOGARITHMIC AVERAGES OF NEMATODE OVA DETERMINATION

Lot	Date of Collection				
	1-15	4-27	5-27	6-28	8-3
1 Ewes.....	.....	4,600	225	180	190
2 Ewes.....	.....	2,800	52	20	24
3 Ewes.....	4	165	91	32	11
1 Lambs.....	.....	.....	37	3,300	3,900
2 Lambs.....	.....	.....	22	1,036	274
3 Lambs.....	.....	.....	.....	793	48

the gains shown for Lot 2 were very unsatisfactory. Lot 2 was given the same phenothiazine-salt mixture but followed the untreated sheep of Lot 1 in the pasture rotation. The gains made in Lot 1 were also unsatisfactory; however, the sheep of Group b and c did make satisfactory gains after treatment.

EGG COUNTS

In Table 3 is given a summary of the nematode ova contents of the fecal specimens as determined by the Stoll technic. Twenty-five fecal samples were collected at monthly intervals from the ewes and from the lambs in each lot. The results given in Table 3 are the logarithmic averages (nematode ova per gram of feces) of each series of 25 samples.

The nematode ova determinations of fecal samples as a means of estimating the degree of parasitism and as a measure of anthelmintic efficiency proved in this experiment to be of limited value. It would be deducted from Table 3, for example, that the ewes in Lots 1 and 2 initially were heavily parasitized at the time they were turned to pasture, but subsequently eliminated most of the infestation. It would be further deduced that the lambs in Lot 1 were more heavily parasitized than those in Lot 2. These deductions are not supported by observations on comparative rates of gain, mortality figures, and post-mortem examination. Just why nematode ova determinations of fecal specimens according to the Stoll technic failed to cor-

TABLE 4.—CONSUMPTION OF THE PHENOTHIAZINE-SALT MIXTURE

Period	Lot	Lambs	Ewes	Mixture	Consumption		Average daily consumption of phenothiazine
					Total	Average monthly	
					lbs.	lbs.	grams
April 25–May 26	2	163	187	1:14	220	0.63	0.60
April 25–May 26	3	157	191	1:14	200	0.57	0.54
May 29–June 28	2	152	184	1:14	177	0.53	0.53
May 29–June 28	3	158	190	1:14	130	0.37	0.38
June 29–August 2	1	96	105	1:9	90	0.45	0.60
June 29–August 2	2	150	183	1:14	225	0.68	0.60
June 29–August 2	3	157	190	1:14	221	0.64	0.57

relate with clinical manifestations is not clear, but probably several factors are involved. One of these would be variations in fecal moisture content. The feces of sheep on dry lot contain less water than those of sheep on pasture; and, the feces of healthy sheep are more solid than those of parasitized animals, the latter often showing profuse diarrhea. An increase in the fecal water content obviously would reduce the ova obtained per unit mass of feces in parasitized sheep. Leiper and Peters determined statistically that variations in weight are more sensitive indicators of anthelmintic efficiency than are egg counts. Our observations tend to support this conclusion.

CONSUMPTION OF THE PHENOTHIAZINE-SALT MIXTURE

During the period of observation 1,173 pounds of the 1:14 phenothiazine-salt mixture were fed to the ewes and lambs in Lots 2 and 3. Group c, Lot 1, consumed 90 pounds of the 1:9 mixture. This represents a monthly consumption of 55 pounds per 100 head of sheep, or a phenothiazine consumption of the drug per animal was 0.55 gram daily.

POST-MORTEM EXAMINATIONS

Portions of the intestinal tracts of 169 lambs from the three lots and the 20 untreated ewes in Lot 1 were examined at the time of slaughter in the packing plant. The intestines were examined for the presence and the relative numbers of parasitic nodules while the abomasum was opened and inspected for the presence of stomach worms. All examinations were necessarily qualitative in nature due to the impossibility of slowing up slaughter plant operations. A summary of these results is given in Table 5.

It is seen from the above that the lambs in Lot 3, even though making satisfactory progress, nevertheless suffered from a degree of parasitic infestation. From the large numbers of nodules found on the intestines, the lambs in Lot 2 evidently were the most heavily parasitized of the groups examined. This group made the poorest gains and suffered the greatest mortality (Table 2).

The ewes and lambs in the control group, Lot 1, as would be expected, showed marked parasitism. It is of interest to note however, that this group, although untreated since

TABLE 5.—POST-MORTEM EXAMINATION OF 189 SHEEP

Lot	Number examined	Stomach worm infestation	Nodulation on intestines		
			Free	Moderate	Heavy
1a Ewes	20	Moderate	0+	4+	16+
1a Lambs	18	Heavy	0	16	2
1b Lambs	15	Moderate	0	9	6
1c Lambs	21	Light	0	16	5
2 Lambs	20	Light	0	0	20
3 Lambs	95	Light	6	83	6

TABLE 6.—AVERAGE WEIGHTS OF LAMBS AT MARKET TIME AND SELLING PRICE

Lot	No. in lot	Av. lot weight	No. marketed	Av. weight of lambs marketed	Selling price, cwt.
		lbs.		lbs.	
1a	19	52.6	18	52.6	$11.25
1b	34	64.6	15	64.6	11.25
1c	96	61.0	21	74.0	11.25
2	150	56.0	20	75.0	11.25
3	157	71.6	95	76.5	14.25

January, suffered less damage from parasitism than the treated ewes and lambs in Lot 2. This apparent inconsistency is explained by the system of pasture rotation used (Table 1). Also of interest is the effect the drenching with phenothiazine, Lot 1b, and the drenching plus 1:9 phenothiazine-salt mixture, Lot 1c, had on the parasitic infestation. It may be reasonably assumed that the exposure to infestation in Lot 2, one of the groups upon 1:14 phenothiazine-salt mixture, was greater than that of Lot 1. Lot 2 suffered the greater damage. The table below gives the weights of the various lots at marketing time, August 3.

Very few of the lambs in Lots 1 and 2 were fat enough to make satisfactory carcasses. The lambs in Lot 3 carried considerable finish.

1944 STUDY

The second phase of the work at the Dixon Springs Experiment Station with the phenothiazine-salt mixture was carried on in 1944. The object of this phase was to compare the efficiency of a 1:14 and a 1:9 phenothiazine-salt mixture as an anthelmintic for ovine nematodes.

TABLE 7.—CONSUMPTION OF PHENOTHIAZINE IN A 1:9 AND A 1:14 PHENOTHIAZINE-SALT MIXTURE

Period	Mixture	No. ewes	No. lambs	Consumption		
				Total mixture	Mixture per head	Phenothiazine per head per day
				lbs.	lbs.	grams
May 1–June 17.....	1:9	219	247	538	1.15	1.23
May 1–June 18.....	1:14	185	202	489	1.26	0.83

PLAN

All sheep at the Station were included in the tests. They were all given individual doses of one ounce of phenothiazine in a drench the first week in January although they had been on a 1:14 phenothiazine-salt mixture since August, 1943. The phenothiazine-salt lick was then discontinued for the remainder of the winter period. All ewes and rams were given the one ounce drench again in April before going on pasture. The lambs were not treated. They were then put on pasture and both ewes and lambs had access to phenothiazine-salt mixtures as follows:

A lot of about 200 ewes and their lambs, Lot 1, was maintained on a 1:14 phenothiazine lick. A similar lot, Lot 2, was maintained on a 1:9 mixture. The remainder of the sheep at the Station were given access free-choice to both 1:14 and 1:9 phenothiazine-salt mixtures.

However, due to the severe drouth which began early in the summer, the pastures intended for Lots 1 and 2 became very poor, and the lots were combined and offered a free-choice of 1:14 and 1:9. Thus, the free-choice lot was the only one carried throughout the grazing period.

Lots 1 and 2 were carried on 1:9 and 1:14 phenothiazine-salt mixtures from May 1 until the middle of June, and the phenothiazine intake is shown in Table 7.

The average daily consumption of phenothiazine per sheep as shown in this table is considerably higher than many other investigators report. The amount consumed in the 1:9 mixture was 48 percent greater than that consumed in the 1:14 mixture. The total mix consumption on the other hand shows only a slight difference. Thus, the amount of phenothiazine consumed varied directly with the concentration of the mixture.

In the group having access to both the 1:9 and the 1:14 mixtures free-choice, 1,029 pounds of the 1:9 mixture were consumed and 1,511 pounds of the 1:14 mixture were consumed. Thus, the phenothiazine intake was about the same, 114 pounds and 108 pounds respectively. The salt consumption was increased about 53 percent when the phenothiazine-salt mixture was fed compared to a 1:9 mixture.

On July 7, 1944, the lambs were weaned from the ewes and put in dry lot for feeding. Their identity was kept according to treatment during the pasture period. When they were slaughtered examination was made of the intestinal tract of the lambs. The results are shown in Table 8.

TABLE 8.—RESULTS OF SLAUGHTER EXAMINATION

93 lambs fed 1:9 phenothiazine-salt mixture:	
Stomach worms (Haemonchus)	*Nodules on Caecum*
64 or 68.8% free	45 or 48.4% free
29 or 31.2% light	41 or 44.1% 1 — 5
	7 or 7.5% 6 — 25
	0 over 25
47 lambs fed 1:14 phenothiazine-salt mixture:	
Stomach worms (Haemonchus)	*Nodules on Caecum*
33 or 70.2% free	22 or 46.8% free
14 or 29.8% light	23 or 48.9% 1 — 5
	1 or 2.3% 6 — 25
	0 over 25

An additional 109 lambs which had access to both 1:9 and 1:14 free-choice were examined for nodules on the intestines. On 59 or 54.1% no nodules were found, 42 or 38.5% showed a light nodulation of 1 to 5 nodules; 4 or 3.7% a medium nodulation of 6 to 25 nodules; and, 4 or 3.7% showed over 25 nodules per lamb.

In general these infestations are very light compared to previous years. The dry lot feeding no doubt had some bearing on this light infestation.

DISCUSSION

It is known that the administration of small repeated doses of phenothiazine to sheep, such as would be received in a salt mixture, probably exerts its major anthelmintic action not through elimination of worms from the intestinal tract, but from a suppressed development of the eggs to the infective larval form. This is clearly indicated in the observations of Shorb and Habermann and of Shorb and Gordon. It appears, therefore, that the greatest benefits should be derived from the feeding of a phenothiazine-salt mixture when sheep, relatively free from internal parasites, are placed upon an uncontaminated pasture.

Such a plan for nematode control in sheep is made more practical by recent disclosures that the larvae of these parasites do not survive as long on pastures as has previously been thought. In the climatic conditions prevailing in the vicinity of Washington, D. C., Sarles, and Kates have shown that pastures heavily contaminated with egg-containing feces during one grazing season become largely non-infective for parasite-free lambs the following spring and summer. Using laboratory procedures only and working with *Haemonchus contortus*, Shorb, also working near Washington, failed to demonstrate over-winter survival of the larvae.

In an earlier and even more revealing article, Shorb showed the survival period of the common nematode larvae parasitic for sheep to be limited on summer pastures even in the presence of abundant shade and moisture. One such contaminated pasture apparently became non-infective for parasite-free lambs in the short space of only two months. It is shown in the same paper that eggs passed during the winter and early spring do not develop to the infective larval stage. Feed-lot infestation of sheep, therefore, except during periods of unusually warm weather, may be of negligible importance.

From the observations reported in this paper and the other papers mentioned, a practical procedure for nematode control in sheep for the northern states might tentatively consist of individual, prepasture treatment of the ewes with the thera-

peutic dose of phenothiazine and their maintenance thereafter at pasture, together with the lambs, on a phenothiazine-salt mixture in the range of 1:9 to 1:14. It is believed a therapeutic dose of phenothiazine should also be given at the end of the pasture season. For best results, the animals should not at any time be maintained upon pasture occupied by parasitized untreated sheep during the preceding two months.

SUMMARY AND CONCLUSION

A lot of 348 sheep (191 ewes, 157 lambs) maintained continuously upon a 1:14 phenothiazine-salt mixture throughout the dry lot and grazing seasons and handled as an isolated unit without contact, direct or indirect, with heavily parasitized, untreated sheep, made a total gain of 8,670 pounds from May 27 to August 3 (10 weeks). One animal died. Their progress was considered satisfactory. Post-mortem examinations of 95 lambs from this group showed internal parasites to be present. The phenothiazine-salt medication, therefore, markedly suppressed but did not eliminate nematode infestation.

A second lot of 350 sheep (187 ewes, 163 lambs) treated individually with phenothiazine at the beginning of the grazing season and maintained thereafter upon the same phenothiazine-salt mixture but placed upon a pasture occupied the previous month by parasitized, untreated sheep, made a total gain of only 10 pounds in the same period. Fourteen of these animals died and three others were sacrificed because of debility. Losses in this group undoubtedly would have been much larger if they had not been treated individually with phenothiazine and placed on clean pasture. Post-mortem examination of 20 representative lambs indicated this group to be heavily parasitized.

A third lot of 359 sheep (197 ewes, 162 lambs) which was not treated after the treatment given at the end of the previous pasture season developed marked symptoms of parasitism at the end of the second month on pasture. It was found they infested the pasture on which Lot 2 was placed the second month of the pasture season. Division of this lot and treatment with a therapeutic dose of phenothiazine of all but 20 ewes and 20 lambs in this lot caused a marked recovery and increase in the gains. Post-mortem examinations, however, showed this lot to be rather heavily parasitized.

The 1944 phase of the work compared the efficiency of a 1:9 and 1:14 phenothiazine-salt mixture in controlling ovine nematodes. The lot receiving 1:9 consumed about 48% more phenothiazine over a 48-day-period than the lot receiving the 1:14 mixture. When offered both mixtures free-choice the amount of phenothiazine consumed was about the same, 114 pounds in the 1:9 mixture and 108 pounds in the 1:14 mixture. The total consumption of the mix, however, when offered free-choice was 53% greater in the case of the 1:14 phenothiazine-salt mixture.

From the observations made during 1943 and 1944 at the Dixon Springs Experiment Station it is concluded that a 1:9 or a 1:14 phenothiazine-salt mixture markedly protected the sheep from excessive parasitism when the animals, relatively free from internal parasites at the beginning of the trial were maintained without contacting, directly or indirectly, other sheep. The same phenothiazine-salt mixture did not, however, protect sheep when they were placed upon a pasture recently contaminated by parasitized, untreated sheep.

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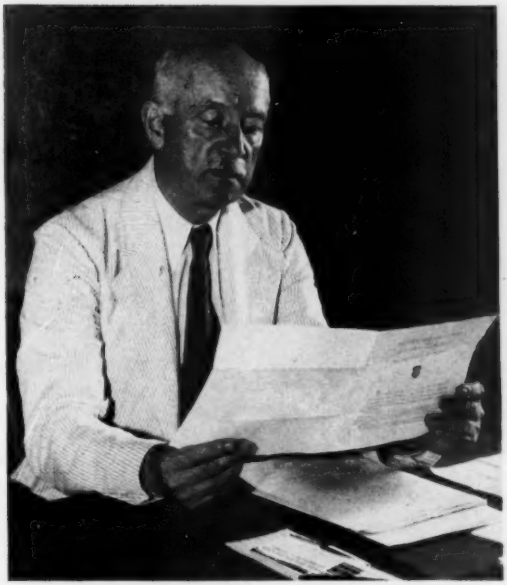
MEMORIALS



JOHN C. HESSLER
1869-1944

John C. Hessler, President of the Decatur College and Industrial School of James Millikin University at Decatur, Illinois, died on July 29, 1944. He was born at Syracuse, New York on November 27, 1869, the son of Jacob R. and Mary Shane Hessler.

Early in life, J. C. Hessler was inclined toward the field of science. He attended the University of Chicago in the very early years of that institution, studying under the guidance of John Ullrich Nef. He was granted the degree of Doctor of Philosophy in 1899. During his years of study at the University of Chicago, he taught in the Chicago high schools and later became an instructor of chemistry at his Alma Mater.

He came to James Millikin University as professor of Chemistry in 1907. He continued in this position until 1917 when he became Dean of the Decatur College. In 1919 he served as Acting President. During his tenure at James Millikin University, he trained many chemistry students who chose this field as their major subject. In those days a thesis, based on a piece of research, was required for a Bachelor's Degree. Dr. Hessler trained his students well in research methods, using as subject matter new deriva-

tives of cyano-acetic acid. Many papers were published on this subject by him and his students in the Journal of the American Chemical Society.

In 1920 Dr. Hessler left the teaching profession to become an Assistant Director of Mellon Institute of Industrial Research at Pittsburgh, Pennsylvania. He served in this capacity for one year, but found that he much preferred teaching. He was called by Knox College at Galesburg, Illinois in 1921 to the Chair of Chemistry, where he remained until 1934.

It had been his plan to retire and to spend much of his time in his northern home at Land's End, Wisconsin, but an urgent call from James Millikin University resulted in his decision to accept the presidency of that institution. He served as president of Millikin until his death in July 1944.

Dr. Hessler was not limited in his field to Chemistry alone. He was an excellent student and teacher of History and Greek, as well as of Philosophy and Religion. His breadth of knowledge was recognized by memberships in Phi Beta Kappa, Sigma Xi, and Phi Lambda Upsilon. He was honored as a Fellow in the American Association for the Advancement of Science. He was a member of the American Chemical Society and of the National Association. He served as president of the Illinois State Academy of Science, of the Illinois Association of Chemistry Teachers, and of the Federation of Illinois Colleges.

Aside from his frequent contributions to the Journal of the American Chemical Society and other educational journals, Dr. Hessler wrote several well-known books. His "Essentials of Chemistry" (with Albert L. Smith) appeared in 1902. Other works that followed were "First Year of Science" (1915), "Junior Science" (1919), "First Year of Chemistry" (1931), "Warbook Manual of Chemistry" (1932), and "Understanding Our Environment" (1939).

Dr. Hessler married Maude C. Hutchins of Chicago in 1891. He is survived by Mrs. Hessler and their two children, Margaret C. Brookes and Herbert E. Hessler.

Memorials are often erected to men who have exerted a profound influence upon their fellows. Among these is a portrait painted by the celebrated artist, Oskar Gross, who was commissioned to do the picture posthumously, by one of Dr. Hessler's students, Dr. Viola M. Bell. The portrait was presented to James Millikin University by Dr. Bell in June 1945. But the memorial that possesses the farthest reaching influence is the memory of the man in the minds of his friends and associates. On a canvas, Mr. Gross painted a great portrait of Dr. Hessler, but on the hearts of his students and associates, Dr. Hessler, himself, painted the portrait of a great gentleman.

—W. F. Henderson,
Chicago, Illinois

MARY MINERVA STEAGALL
1867-1945

Dr. Mary Minerva Steagall was a native of Southern Illinois, born at Golconda November 22, 1867. She was educated in the public schools of Pope County, at Southern Illinois Normal University, Illinois Normal University, the Marine Station at Friday Harbor, Washington, and the University of Chicago. From the latter school she held the degree of Bachelor of Philosophy.

Dr. Steagall taught for fifty years; forty-two of these years were in the schools of Southern Illinois—five in the rural schools, seven in the high schools of Chester and Shawneetown, and thirty at Southern Illinois University. In the other eight years she was critic teacher in the Normal School at Ypsilanti, Michigan.

Dr. Steagall came to Southern Illinois Normal University in 1908 as a critic teacher in the training school. In 1910 she was transferred to the department of mathematics, and in 1913 to the department of biology, becoming head of the department of Zoology when Biology was divided into Botany, Zoology, and Physiology. She played a very important part in the formative period of the college, helping to raise it to the standard of a first rate college. She retired in 1938 as professor of Zoology. Upon her retirement, some 100 of her former students gave a dinner for her and presented her with a book of some 200 appreciative testimonial letters, voicing the high esteem in which she was held by students, associates, and friends.

Dr. Steagall was an inspiring teacher. She was highly critical of the work of her students, but always tempered her criticism in such a way that the student, instead of being offended, was spurred to greater efforts. An index to her influence is the fact that some three hundred students worked out majors or minors in Zoology while she was a teacher in the college. Of this number, more than half have completed work for advanced degrees in other universities. At least 19 have Doctor of Philosophy degrees, and are teaching in colleges and universities. A number of these people have distinguished themselves nationally. More than 60 have entered the medical profession. Others are teachers, nurses, veterinaries, laboratory technicians, dentists, and so on. Many of her students have held assistantships or scholarships in such colleges and universities as Illinois, Minnesota, Missouri, Iowa, Oberlin, Ohio State, Nebraska, Mississippi, Louisiana, Pennsylvania, and Michigan State.

In her classes, Dr. Steagall continually stressed that the student must keep an open mind; that Science recognizes no political or racial boundaries; and that a person should always receive full credit for his achievements, no matter what his creed. Her personal quality was further strengthened by a keen sense of humor. She was quick to perceive all the possibilities in a situation, and to make adjustments to turn everything to good account. Her students and friends seldom meet nowadays but what sooner or later, in some discussion, her remarks on this or that occasion are quoted, and her actions remembered.

Students of Dr. Steagall were not forgotten upon graduation, but continued to receive inspiration from their teacher by way of correspondence with students and friends and family. She devoted a part of each

day, even to the very last day, to letter writing. Her "thank-you" notes were always a marvel to her many friends.

In the field of Science she was nationally recognized. Her research was in the field of Ecology, with special reference to the relationship of soil acidity to plants and animals. She was recognized as an authority on the ferns of Illinois. As a member of many scientific societies, she frequently presented papers at state or national meetings of these societies. She was made a Fellow of the American Association for the Advancement of Science, in recognition of her ability as a teacher and research worker. This is an honorary recognition, and one of the highest that the American Association for the Advancement of Science bestows.

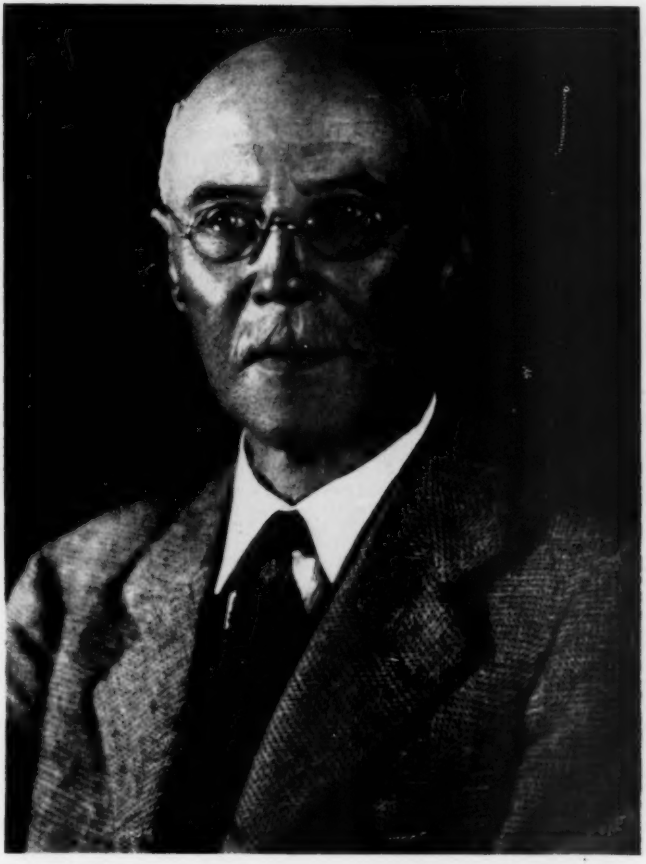
Her civic interests were wide. She was keenly interested in community problems, and active in local and state clubs of various kinds. Upon the establishment of the Park Board for the city of Carbondale, Dr. Steagall became a charter member of the Board. After her retirement from teaching, she was chairman of a committee to lay out Nature Trails for Giant City State Park, and edited six bulletins on the natural phenomena to be found, in that park at each season of the year. As a member of the National Committee on Conservation and the Preservation of Natural Areas, she had an important part in helping the Ecological Society of America set aside as National Monuments and Parks undisturbed areas valuable for scientific study. These areas are scattered throughout the United States. In recognition of her distinguished record in educational and civic affairs, she was selected by Delta Kappa Gamma as one of three Southern Illinois women who had contributed most to the development of the state.

Two hobbies from which Dr. Steagall derived a great deal of pleasure were photography and gardening. Every week yielded new pictures of friends, gardens, and places of interest that she had visited. Her garden, always well cared for, was open at all times to everyone. Presents of flowers, bulbs, and plants went to all her friends.

She was also an experienced and untiring traveller. She had the mark of a truly educated person—the ability to put all persons with whom she was associated thoroughly at ease, no matter what their station. Practically every vacation she spent in travel—in the states, in Canada, Alaska, Mexico, Europe, and in 1940, around the world. From these travels she always came back with a wealth of experience to share with her students and her friends. In 1941 she made her last trip to the West, going by bus, through the Black Hills; to the Bitter Root Mountains, where she went on a pack trip of nearly two weeks; thence westward to Washington, Oregon, California; and home, by way of Arizona and New Mexico. Former students and associates are located all along this route of her travels.

In the passing of Dr. Mary Steagall, the college has lost a distinguished scholar and teacher. All who knew her have lost a friend. She herself would most probably have us feel, not that she has gone, but that she is once more away on those travels from which she derived in part the quality that kept her young for nearly eighty years.

—Willard Gersbacher,
Southern Illinois Normal University, Carbondale.



WILLIAM TRELEASE
(1857-1945)

Dr. William Trelease, so well known as the early head of the Missouri Botanical Garden, later of the Department of Botany at the University of Illinois, and since his retirement in 1926 as the chief investigator of American Piperaceae, died at Urbana on New Year's day, 1945. He had been continuously active until about eleven weeks before his death.

An extended account of the long professional career of Dr. Trelease is unnecessary here. The principal facts are summarized in the article by J .T. Buchholz in Science of February 3, 1945 (Vol. 101, No. 2617, pp. 192-1913), and there is a rather

full history, to 1927, in L. H. Pammel's privately printed tribute entitled "Prominent Men I Have Met. III Dr. William Trelease" (Ames, Iowa, 1927; 84 pp.). Of this, pp. 75-84 form a list of Dr. Trelease's publications, from 1879 to 1927. For this bibliography Dr. Pammel was under obligation to Dr. Stella M. Hague.

William Trelease was born in Mount Vernon, N. Y. February 22, 1857. At Cornell University he earned the B.S. degree (1880). He taught botany at the University of Wisconsin from 1881 to 1884. His graduate study, carried on during summers at Harvard, resulted in a doctor's degree in 1884. He became in 1885, Engelmann professor of the Shaw School of Botany, at Washington University, St. Louis. After the death in 1889 of Henry Shaw, Trelease carried out elaborate plans for converting Shaw's garden and arboretum into a research institution and training school for floriculturists and gardeners, as well as an outstanding collection of living plants. Its herbarium and library (including the Sturtevant library of pre-Linnaean Botany), and its publications, are among the world's foremost. The development of the garden and the activities of its personnel are recorded in its Annual Reports.

A natural consequence of his appointment at St. Louis was Trelease's interest in Dr. George Engelmann, his preparation (with the encouragement and help of Asa Gray) of Engelmann's collected botanical works, and of his continuation of systematic and ecological work on many of the groups Engelmann had studied (Yucca and its relatives, Agave, oaks, mistletoes, and various tree genera.)

Dr. Trelease resigned in 1912, and in 1913 became head of the botany department at Illinois. When in 1917 the state survey agencies were reorganized under the Illinois State Natural Resources and Conservation Board, he became one of its members.

It is hard to realize the extraordinary versatility of his knowledge, his researches, his contacts with able men in science and in other fields, his administrative and other activities. Early in his career he had formed the habit of travel to far places. Though time for advance preparation and for study in the field was always limited, many of these journeys resulted in noteworthy publications on particular groups of plants or on the general flora in such places as Mexico, the West Indies, and the Azores. The volume of his accomplishment is very great. Exceptional aptitude and industry, combined with unusual opportunity, operated over a prolonged span of years to produce this volume. The list of his writings to 1927 take up ten printed pages; after 1927, two closely typed pages. The number of species described by Trelease, as estimated by Dr. Buchholz, is over 2500. His productive career from the earliest publication in 1879 until recently covered sixty-five years.

In attempting to analyze Dr. Trelease's researches, it was at first thought that one could divide his production into chronological periods. This was found to be only roughly possible. His first publications, resulting from employment as entomologist with the United States Department of Agriculture, dealt with relations between flowers and insects. The great interest in Darwin's studies was then at its height. Trelease by omnivorous reading on pollination, quickly mastered this subject, and in the Bibliographical Record in successive numbers of Psyche during 1881, listed titles of

practically all papers in that field, adding many brief annotations. His comprehensive accounts of nectar and nectar secretion are still standard. Some of Trelease's articles and reviews on pollination were soon reprinted or translated in European journals, and this quickly helped to make him widely known.

His botanical studies at Harvard with W. G. Farlow and his teaching at Wisconsin were principally concerned with lower plants. Between 1884 and 1904 he published many papers on bacteria, fungi, and plant diseases. He translated a Danish text in bacteriology by Salamonson, and also Poulsen's Botanical Microchemistry. He wrote the systematic accounts for lower-plant groups, including ferns, for the reports of the Harriman Expedition to Alaska.

Between 1892 and about 1912, a majority of Trelease's published works dealt with Yucca, Agave, and their relatives. Other plants in rather wide variety were also treated: prominent among these were woody plants of many families, with interest centering in oaks and in mistletoes as the next major groups. The pepper family was studied after 1920, and became Dr. Trelease's main interest. As separate publications or as parts of more inclusive floras for particular countries, he has given detailed accounts of peppers of Panama, Costa Rica, Mexico, Hispaniola, the Duida highland, and several South American countries.

The historical development and the spatial distribution of the plant groups studied, receive attention in his descriptive works, and were emphasized in such publications as his Agave in the West Indies. The bearing of the distribution of the flora of Central America and the Antilles on former land connections, and the geography of American peppers.

Many other publications cover a wide range of topics, including swamps of southeastern Missouri, history of botany; techniques in garden, herbarium, and laboratory; biography, biliography, identification of trees in winter condition; articles in two cyclopaedias of horticulture, and a city plan for St. Louis.

For many years Dr. Trelease had been an active member of the Illinois Academy of Science. He contributed several articles to the Proceedings, on oaks, and on the chestnut in its local native occurrence in southern Illinois. His prominent part in many other scientific societies may be seen from the article in Who's Who in America.

Dr. Trelease's home life was admired by his many friends. He was married in 1882 to Julia M. Johnson. Of his four sons, the second, Sam Farlow Trelease, whose botanical career began on his father's expeditions in Mexico, is professor of botany at Columbia University.

The many students and associates of William Trelease will remember him as a helpful friend and counselor, as a leader in American science, and as an unassuming but famous botanist.

—A. G. Vestal,
University of Illinois.

ACADEMY BUSINESS

SECRETARY'S REPORT ON THE BUSINESS OF THE ILLINOIS STATE ACADEMY OF SCIENCE For the Year May 7, 1944 to May 5, 1945

Compiled by LEO R. TEHON, *Secretary*
Illinois State Natural History Survey, Urbana

During this year the Illinois State Academy of Science was more acutely affected by conditions resulting from the nation being at war than in either of the earlier war years. The calling of scientific personnel from the universities, colleges, and secondary schools of the State to the service of the nation in civilian capacities and in the armed forces brought about a marked reduction in active membership. Unrest among teachers, resulting in movements from this to other states in search of higher incomes with which to offset increased costs of living and burdens imposed by large income taxes, and other factors, have also tended to reduce the membership of the Academy. Restrictions on travel imposed by the Office of Defense Transportation and refusal by that office of permission for the Academy of Science to hold its regular annual meeting also adversely affected the program of the Academy.

To the officers, the chairmen of sections, the chairmen and members of standing and special committees, and other officials the Academy is more than usually indebted for service exceptionally loyally rendered under extremely difficult and discouraging circumstances.

1. COUNCIL MEETINGS

Four meetings of the Council were held as usual during the year, President Otis B. Young presiding at each meeting

The first Council meeting was held at DeKalb on May 6, 1944, following the annual meeting of the Academy at DeKalb. The newly elected officers were introduced, the invitation to hold the 1945 Academy meeting at Illinois State Normal University, Normal, was accepted, Dr. Ralph U. Gooding was appointed Second Vice-President and Chairman of the Committee on Local Arrangements for the 1945 meeting, and the time and place of the second Council meeting was set.

The second Council meeting was held at Urbana on November 18, 1944, with eleven members present. Reports were heard and approved from the treasurer, secretary, committee on the budget, committee on codification of council actions, the editor, the librarian, the collegiate section coordinator, and the general representative of the Junior Academy. The secretary was authorized to request libraries receiving the *Transactions* but not subscribing or offering exchanges, to subscribe at the rate of one dollar per year. A proposal for an *Illinois Journal of Science* under Academy sponsorship was discussed and a committee consisting of Dr. Hanford Tiffany, chairman, Dr. A. E. Emerson and Mr. J. C. McGregor was appointed to investigate all phases of the proposition. A discussion of post-war objectives for the Academy led to a proposal, by Dr. Lyell J. Thomas, of a committee on living memorials: this committee, as appointed, consists of Dr. Thomas, chairman, Dr. Nelson Spaeth, Mr. Joel C. Loomis and Dr. M. M. Leighton. From a discussion of possible permanent headquarters for the Academy, it developed that the projected new State Museum building had been so planned as to provide expanded facilities to meet the Academy's needs

The third Council meeting was held at Normal on February 24, 1945, with 14 persons present, including members of the council and section chairmen. Reports were heard and approved from the treasurer, secretary, librarian, committees on membership, affiliations, and codification of council actions. The Secretary reported that the Academy would receive $206.50 from the A.A.A.S. to be used for research grants. Following the announcement that the Office of Defense Transportation had refused the Academy permission to hold its annual meeting, discussion as to how the business and activities of the Academy could

be carried on brought forth the following resolution, which was adopted: *It is the opinion of this body that the duty of doing the executive work of this association and of determining how the officers and standing committees shall be elected belongs to the Council in this emergency.* Procedures agreed upon included the following: the appointment of a nominating committee as usual; submission of the slate proposed by the nominating committee to the membership with opportunity for the membership to vote by mail; the holding of an executive session on May 5, 1945, in place of the annual meeting; section chairmen to solicit papers for the Transactions and to submit them at the executive session. The President appointed the following committees to function in the interim and report at the executive session: *Committee on Nominations*, A. R. Wanless, chairman, L. J. Thomas, and R. F. Paton; *Committee on Auditing*, W. W. Grimm, chairman, W. Thomas, and L. P. Elliott; *Committee on Resolutions*, T. T. Quirke, chairman, Walter B. Welch, and M. M. Leighton; *Committee on Necrology*, Gilbert Wright, chairman, A. G. Vestal, and R. U. Gooding. To fill the vacant chairmanship of the Botany section, Dr. Hiram F. Thut was selected.

The fourth Council meeting was held at Normal on May 5, 1945, as part of the executive session of the Academy.

2. EXECUTIVE SESSION

The regular annual meeting of the Academy having been prohibited by direct order of the Office of Defense Transportation, an executive session of the Academy was held, in lieu of the annual meeting, at Illinois State Normal University, Normal, on May 5, 1945. In attendance were the officers of the Academy, Council members, section chairmen, chairmen and members of standing and special committees, and several past presidents. The attendance was within the limit imposed by the Office of Defense Transportation.

The executive session opened at 9:30 a. m. and adjourned at 4:30 p m., with President Otis B. Young presiding, and was divided into five periods, the fourth Council meeting of 1944-45 and a general business session in the morning, a period for the President's address, a final business session, and the first regular Council meeting of 1945-46 in the afternoon. At a noon luncheon the recipients of A.A.A.S. fund research awards were announced.

Reports of officers and of special and standing committees were heard and approved, the mail vote for new officers was canvassed and officers, representatives, and standing committee chairmen and members, as shown on pages 2, 3 and 4, were declared elected. Section chairmen presented, by title, 18 papers for submission to the committee on publications, and final date for the submission of additional papers was set as May 19, 1945.

Among the business items, a proposed new State Museum building received much consideration, because of the vital interest of the Academy in the development of the State Museum to serve more adequately the needs of all citizens of the State. A special committee on State Museum Building, consisting of Dr. Percival Robertson, chairman, Dr. C. L. Furrow, Mr. F. W. Aldrich and Dr. E. L. Stover was appointed, the duty of the committee being to advocate the immediate construction of a new State Museum building as a part of the State's postwar construction program.

3. SECTION MEETINGS

Memberships of the Chemistry section and the Physics section being closely allied with affiliated teachers organizations, the chairmen of these sections arranged for joint meetings and presentation of papers with the Illinois Chemistry Teachers Association at Normal on April 28, 1945, and with the Illinois Physics Teachers Association at Urbana on May 5, 1945. Papers presented by Academy members at these meetings were submitted to the Academy for publication. Dr. G. C. Finger was elected chairman of the Chemistry Section and Dr. C. E. Ireland was continued as chairman of the Physics Section for the coming year.

4. REPORT OF THE COMMITTEE ON BUDGET

The committee on budget met in Galesburg, August 26, 1944. After giving consideration to past accounts of the Academy and taking into consideration the amounts, as estimated by the treasurer, to be received by the Academy during the 1944 fiscal year, the committee agreed that the following recommendations be made.

1. In view of the recent decline in membership of the Academy and the

further decline to be anticipated during the war, resulting in decreased income from annual dues, this committee recommends that the expenditures of the Academy for 1944 be kept within the estimated income for the year of $715.00.

2. In order to accomplish the end aimed at in recommendation 1, this committee further recommends that the expenditures of the Academy be apportioned in the following amounts, which are adjustments of similar expenditures made in recent years

Officers' expense	$ 30.00
Travel to interim council meetings, postage, and other incidental costs.	
Treasurer's office	25.00
Postage and other costs necessary in the collection of dues and fees and the handling of the Academy's funds.	
Secretary's office	50.00
Postage, mimeograph supplies, telephone and telegraph, and other costs necessary to the transaction of the Academy's business.	
Stenographic services	25.00
As authorized for the Secretary's office.	
Editor's expenses	10.00
Corporation registration	2.00
Transportation of Transactions	85.00
Honoraria, as authorized by the constitution:	
Secretary	100.00
Editor	150.00
Annual meeting:	
Program development, including section chairmen's costs	48.00
Program printing	150.00
Lecturer	20.00
Total	$695.00

3. This committee recommends that the sum of $25.00 be made available to the committee on membership, for the purpose of enlarging the Academy's membership. It considers that the work of the committee on membership should be self-supporting annually, that sums advanced in its behalf should be returned to the Academy during the year in the form of initiation fees and dues, and that amounts additional to the $25.00 recommended may be made available if returns justify doing so.

4. With respect to Junior Academy funds, this committee recommends that, in view of the curtailment in Junior Academy activities, expenditures by the Junior Academy amount to not more than $100.00, and that all funds collected in excess of this amount be retained by the treasurer for use in postwar development of the Junior Academy.

5. This committee recommends that life membership funds held by the treasurer be invested in behalf of the Academy in Series G government bonds, that such funds, and the investment of them, be regarded as additions to the Academy's endowment fund, as required by the constitution, and that interest derived from such bonds be added to the income of the Academy.

6. This committee recommends that excess money held in bank on the Academy's checking account, including Junior Academy funds, be invested, in amounts determined by the experience and judgment of the treasurer, in short term government bonds, and that any income from such investments be added to the income of the Academy.

This report has been read and approved by each member of the committee on budget, and his signature is attached hereto .

(Signed) C. L. Furrow, *Chairman*
Carl G. Hartman
Leo R. Tehon, *Secretary*
John Voss, *Treasurer*

5. REPORTS OF THE TREASURER AND THE COMMITTEE ON AUDITING

(a.) Report of the Treasurer for the Year May 1, 1944 to April 30, 1945

Receipts

Balance on hand April 30, 1944		$ 1,134.32
Dues and initiation fees:		
Annual members	$ 586.10	
Affiliated societies	2.00	
		588.10
Life memberships		199.00
Interest from Forbes and Meyer real estate		18.00
Refund on postage		11.69
Library		1.00
Research grant by the A. A. A. S.		201.50
Junior Academy:		
Dues	45.60	
Sustaining members	310.00	
Sale of pins	33.08	
		388.68
		$ 2,542.29

Expenditures

Officers' expenses	$ 30.47	
Section Chairman's expenses	18.19	
		48.66
Postage, Treasurer's office		18.00
Expenses of Secretary		67.86
Corporation registration		1.00
Research grants:		
C. L. Bieber	50.00	
C. C. Hoff	50.00	
W. M. Reid	51.50	
W. Welch	50.00	
		201.50
Secretary, honorarium		150.00
Editor, honoraria (1943-44, 1944-45)		300.00
Librarian, postage		61.72
United States Savings Bonds, Series "G"		200.00
Junior Academy		63.82
		$ 1,112.56
Balance in the Commercial National Bank of Peoria		1,429.73
		$ 2,542.29

Statement of Resources, April 30, 1945

Balance in the Commercial National Bank of Peoria	$ 1,429.73
Certificate of Interest No. 13 for Forbes Building (Chicago) for an Aggregate Principal Amount of $300.00	value unknown
Certificate of Interest No. 15 for Meyer Block Leasehold (Chicago) for an Aggregate Principal Amount of $300.00	value unknown
United States Savings Bonds, Series "G"	200.00
	$ 1.629.73

The membership of the Academy consists of 54 life members, 48 new annual members, 8 new life members, 17 sustaining members, 476 members paid up to and including the year 1945, 130 members one year in arrears, 39 members two years in arrears. The total membership is 772.

During the year 7 members have resigned, 7 have died, and 46 have removed leaving no forwarding address.

Respectfully submitted,
(Signed) John Voss, *Treasurer.*

(b.) REPORT OF THE AUDITING COMMITTEE

May 2. 1945

Illinois State Academy of Science
200 Dixon Avenue
Peoria, Illinois:

This is to certify that at the close of business April 30, 1945, balance standing to the credit of the account of Illinois State Academy of Science on our books was $1,429.73.

Yours very truly,
(Signed) J. W. LUKE, *Cashier*
Commercial National Bank of Peoria
Peoria, Illinois

May 3, 1945

We have examined the Treasurer's records and find them correct. The present financial status of the Academy is as follows:

Cash on hand on deposit with the Commercial National Bank of Peoria	$ 1,429.73
Series "G" U. S. Savings Bonds	200.00
Meyer Block Leasehold Certificate No. 15 original value of $300.00	value unknown
Forbes Building Leasehold Certificate No. 13 original value of $300.00	value unknown
Total Assets	$ 1,629.73

Of the total assets the sum of $324.86 represents the Junior Academy balance. Sustaining members contributed $310.00 during the year to the Junior Academy.

Respectfully submitted,
Committee on Auditing
(Signed) W. W. GRIMM
WALTER W. THOMAS
L. P. ELLIOTT

6. REPORT OF THE LIBRARIAN

Upon recommendation of the Academy Council, the *Transactions* Volume 37, 1944, was published as a single volume and not issued as a quarterly. The publication went into the mails early in January, 1945. It was printed and distributed by the Illinois State Museum according to the usual policy. Mailing expenses were covered by the Academy, from its treasury. As now printed, the *Transactions* may be sent at regular book rate.

Exchanges with other scientific societies were maintained. A demand exists among exchange libraries for out-of-print volumes of the *Transactions*. Members willing to part with old copies should notify the librarian. Nearly all volumes published previous to volume 24, 1931, are now out of print.

A further demand for back volumes is anticipated by the librarian to aid in the restoration of scientific libraries devastated by the war. Members wishing to donate copies of their *Transactions* for this purpose are advised to notify the librarian.

As approved by the Council, publications received on exchange by the Academy librarian are incorporated into Illinois State Museum library. These publications are available through loan to members of the Academy.

Respectfully submitted,
(Signed) GILBERT WRIGHT, *Librarian*

7. REPORT OF THE COMMITTEE ON NECROLOGY

(See also pp. 127-133 in this volume.)

The Illinois State Academy of Science has recently lost through death the following esteemed members:

MR. WILLIAM F. E. GURLEY (life member), The University of Chicago, whose death occurred June 27, 1943.

DR. JOHN C. HESSLER (life member), James Millikin University, Decatur, Illinois, whose death occurred July 29, 1944.

MISS MARY STEAGALL, Southern Illinois State Normal University, Carbondale, whose death occurred March 28, 1945.

DR. JOSEPH L. SHERRICK, Monmouth, Illinois, whose death occurred July 28, 1944.

DR. M. T. TOWNSEND, Illinois Wesleyan University, Bloomington, whose death occurred October 20, 1944.

DR. WILLIAM TRELEASE (life member) University of Illinois, Urbana, whose death occurred January 1, 1945.

MR. CHARLES M. TURTON (life member) Chicago, Illinois, whose death occurred on November 24, 1937.

Respectively submitted,
(Signed) GILBERT WRIGHT
Chairman, Committe on Necrology

9. REPORT OF THE COMMITTEE ON AFFILIATIONS

As a result of very profitable correspondence with every member of the committee and many letters to and from the secretary of the Academy, a policy for the year was established:

1. A few members of the committee agreed to try to interest the few Science Clubs known to them, that are not already sustaining members, to become such.
2. Former sustaining members would be contacted by the secretary of the Academy.
3. Letters should be written to companies dealing in scientific supplies, pointing out to them the advantages of assisting the work of the Junior Academy and that by becoming sustaining members of the Academy they would further this work. Twenty such letters were written and two memberships totaling twenty dollars were obtained. Letters from four others were received, in which interest was indicated, and either more information was asked regarding the Junior Academy or we were asked to present the same matter in another year.

Respectfully submitted,
(Signed)
PERCIVAL ROBERTSON, *Chairman*

10. RESOLUTIONS REPORTED BY THE COMMITTEE ON RESOLUTIONS AND APPROVED BY VOTE

(a.) RESOLUTION HONORING WILLIAM TRELEASE

WHEREAS, The Council of the Illinois State Academy of Science, meeting at Illinois State Normal University on February 24, 1945, has been apprised of the death of William Trelease, for many years a member of the Academy; be it

Resolved, That the Council, on behalf of the Academy, pays honor to the memory of William Trelease, as noted botanist, productive researcher, servant of the people, constructive force as head of the Botany Department of the University of Illinois, and member of the Illinois State Board of Natural Resources and Conservation, teacher and leader of botanists, father of scientists, and life member of this Academy; and be it further

Resolved, that this resolution be spread upon the minutes of the Illinois State Academy of Science.

(b.) A RESOLUTION REGARDING AN ILLINOIS STATE MUSEUM BUILDING

The Illinois State Museum is an institution rendering unique service to the entire Commonwealth in education, in human culture, and in the utilization of natural resources. It has already discharged important functions in the development of the State and will do much more when facilities are given, but it has reached its absolute limit under present conditions.

The Illinois State Academy of Science, representing all the scientific interests of the State, familiar with the present limitations of the State Museum and cognizant of the essentiality of the State Museum to the fullest development of science, art, industry, and commerce in Illinois, urges that provision be made for immediate construction of the proposed State Museum Building. The Illinois Academy of Science earnestly recommends that the erection of this building be given high priority in the building program presented to the present General Assembly.

11. REPORT OF THE COMMITTEE ON PREMEDICAL EDUCATION

Following the 37th Annual Meeting in 1944, a more thorough study of statistics was made, and the corrected report then became the final report. Only minor changes were made. In June, 1944, there was an informal meeting of the national officers of Alpha Epsilon Delta, national premedical fraternity, with a number of invited guests, during which there was some discussion of the work of this committee. As a result, the chairman was asked to present the report in full at a symposium under the sponsorship of Alpha Epsilon Delta during the Cleveland session of the A. A. A. S. Owing to last minute difficulties, he was unable to attend, but a brief informal report was made by Dr. Victor Johnson. Subsequently, the report was published in *The Scalpel*, official organ of Alpha Epsilon Delta. More recently, the report was published in the *Illini Scope*, the student publication of the University of Illinois Chicago Colleges.

In October 1944, the chairman read a paper, incorporating the report, before the annual meeting of the Association of American Medical Colleges. This will be published in the official Journal of that organization.

After much informal discussion and correspondence as to functioning of the committee, it seemed advisable to reallocate the work as follows:

1. A modified questionnaire will be presented to students in the medical schools in Illinois so that each class not previously canvassed will be asked to cooperate. The individual colleges will be asked to sponsor this activity but to turn over the returns to the chairman of this committee for study and analysis and the results will be filed with the secretary of the Academy.
2. Professors Bockstahler and De Bruine have been asked to serve as a subcommittee to study further the place of Physics in the premedical program and make further recommendations.
3. Professor Hall has been asked to function in a similar capacity with regard to English. Both subcommittees are accorded the privilege of inviting collaboration from sources other than the membership of the Academy if they so desire.

An analysis of student comments in the questionnaires previously used regarding the place of Latin and Greek was incorporated in a paper for the *Classical Outlook*.

If it is desired that the committee continue to function officially, it is recommended that the following names be not included: Drs. Foley and Reynolds, Mr. A. C. Brookley. The other members will continue to serve if it is desired, or will be glad to give way to other appointments if this should be desired.

(Signed) C. I. REED, *Chairman*

12. REPORT OF THE COMMITTEE ON RESEARCH GRANTS

I herewith transmit the recommendations of the committee on research grants of the Illinois State Academy of Science. After careful consideration by mail followed by a face-to-face discussion by Doctors Ball, Freeland and myself, we recommend the following allotments:

Dr. C. L. Bieber of North Central College, Naperville, $50.00; to enable him to proceed with additional field work on a project dealing with basal Galena and Decorah relationships.

Dr. Mary Gojdics of Barat College, Lake Forest, $56.50; to aid her in preparing a monograph of the genus *Euglena*.

Dr. C. Clayton Hoff of Quincy College, Quincy, $50.00; for use in continuing his work on pseudoscorpions.

Dr. K. Lucille McClusky of St. Xavier College, Chicago, $50.00; to aid her in the study of methods of the preparation of ethers of the type found in thyroxin.

Total amount available.....$206.50
Total allotment recommended.$206.50

We regret that lack of funds prevents our making recommendations for aid to other worthy applicants. We further recommend that each person receiving a grant-in-aid be asked to report progress to the secretary on or before the next annual meeting of the State Academy.

Respectfully submitted,
(Signed) W. C. ALLEE, *Chairman*

Ohio Acad. of Sci.